**A time-responsive exploration into coastal
communities adaption to sea-level rise**

A large background graphic featuring a dashed line that starts from the bottom left and extends towards the top right, ending in a small cross symbol. The background is divided into a light yellow upper section and a blue lower section with a wavy, textured pattern. The title text is written in a large, black, cursive script across the center.

Lapping at the edges

by Zoe Maren Farr D'Ath

**A 120 point thesis submitted in partial fulfillment of the
requirements for the degree of Master of Architecture
(Professional)**

Victoria University of Wellington, School of Architecture

2020

Fig. 0.01. Collage

0.0.1

THANKS

Firstly, I would like to thank my supervisor, Shenuka de Sylva, for your support throughout this year. You allowed me to progress my research in a direction aligned with my passions. You provided space when that was necessary, but provided critical feedback to keep me on the right path. You continued to remind me of the core idea, when I continued to attempt fitting three in one. Your extreme body of knowledge has been so valuable to this thesis, and it has been a pleasure to learn from you and work with you.

To my friends and family, thank you for being my rock throughout these five years of study. You have dealt with a stress-ridden, sleep-deprived Zoe and then continued to hang out with her.

To all the Architecture friends, thank you for creating joy within the countless all-nighters together (more often than not chocolate/coffee-fueled hysterics). These friendships have been so special, and I look forward to seeing what every one of you succeed in the future. My family, I have been fortunate enough to attend university and complete a Masters because of your unwavering support. The constant interest in my success has led being continually asked questions that I will try and avoid such as, "What are your plans next year?" and "Have you found a job yet?". You continue to question and challenge me, keeping me grounded and encouraging me to work hard and make the most of a situation, and for that I am very grateful.

ABSTRACT

Global warming poses an increasingly relevant risk across the globe. Among one of these risks is sea-level rise. The total population exposed to flooding could triple from 50 million people to 150 million by the 2070's due to sea-level rise and increased occurrence of storms, subsidence, population growth and urbanisation (Adeyeye & Emmitt, 2017). Projections suggest that managing a 2°C rise in temperature, as per the Paris Agreement, will still cause a rise of 0.36 to 0.87m by 2100. Sea-level rise is a lagged representation of the effects of rising temperatures. This response time is considered in the research and design process timelines.

'Lapping at the edges' proposes a design strategy that reinvents architecture and living environments to respond to sea-level rise. This proposition explores how design, as both a process and outcome, can encourage a shift in mentality from defending against, to engaging with water.

Two processes have driven this research. 'The Execution' explores flooding and sea-level rise and considers how to respond to this. Reviewed literature and case study analysis provided categories of architectural typologies. The adaptability criteria allows for cross-comparative analyses of each case study and how successful their respective proposals are at being adaptable. The Palette of Solutions proposed in this thesis is a library of urban and architectural ideas designed to rethink urban environments and their relationship to water. These ideas can be realised over time and in diverse arrangements for a myriad of scenarios and settings. 'The Idea' refers to how

adaptability can be applied to urban development - exploring the maximum alternatives with design iterations.

Adaptability, informed by the literature review and the creation of the timeline, is analysed through 'The Execution'. The methodology analyses how the 'execution' and 'idea' can complement one another, creating a back and forth of research methods and design methods to execute the final idea.

The design proposes a series of changes over 70 years, from 2030 to 2100, resulting in The Hub. An idea that allows modification for most settings provides a vision of the future of coastal architecture, applied to the context of Kilbirnie, Wellington. This thesis is presented in a chronological order, to showcase the progression of beliefs, lifestyle, behaviour and architecture accordingly. Projections of living with water create catalysts for adaptive urban development. The Hub proposes floating infrastructure that combines architecture and urban design techniques. Integrating these solutions into a circular economy concept generate prosperity long-term. This research is utilised as a comprehensive study on sea-level rise, and the responsive design opportunities that are possible. The Hub is a representation of the possibilities of sea-level rise and the responsive architectural solutions. The research has achieved the intention to generate awareness of the impacts of sea-level rise, and create criteria which encourage a different approach to these dynamic living environments.

CONTENTS

ii	THANKS
vi	ABSTRACT
01	Chapter 01: INTRODUCTION
02	1.1 The Question
04	1.2 The Strategy
11	Chapter 02: THE PROBLEM
12	2.1 Climate Change
16	2.2 Sea Level Rise
20	2.3 New Zealand
25	2.4 Summary: The Problem
27	Chapter 03: THE CONCEPT
28	3.1 Response Strategies
38	3.2 Decentralising Water
43	3.3 Adapt to water
51	Chapter 04: THE CRITERIA
52	4.1 Theories: Adaptability
61	4.2 Built Environment
65	4.3 Development of the Criteria
69	4.4 Adaptability Criteria

77	Chapter 05: THE SETTING
78	5.1 The Timeline
86	5.2 Literature Review
88	5.3 We are rising
92	5.4 Selection of site: Kilbirnie
107	Chapter 06: THE ANALYSIS
109	6.1 The Typologies
111	6.2 Floodable Architecture
125	6.3 Stilted Architecture
135	6.4 Floating Architecture
146	6.5 The Reflection
151	Chapter 07: THE RESPONSE
154	7.1 Palette of Solutions
177	7.2 Ecological Area
184	7.3 Living on Water
189	Chapter 08: THE DESIGN
190	8.1 Iterative Design
205	Chapter 09: THE HUB
209	9.1 Urban Precedents
221	9.2 Circular Economy
223	9.3 Design Decisions
228	9.4 Physical Model
243	Chapter 10: THE REFLECTION
244	10.1 The Hub
246	10.2 The Process
xxx	xxx
251	Bibliography
252	11.1 Works Cited
262	11.2 List of Figres

THE INTRODUCTION

1.1 *The Question*

02

1.2 *The Strategy*

04

intro.

1 = the question

[This thesis interrogates the capacity of our living environments to become adaptable over a long-term planned issue of sea-level rise, and how architecture can respond parallel to this.]

1.1.1

How might time-responsive adaptability as an architectural concept be utilised as a response to the effects of sea-level rise on coastal communities?

This question relates to a broader discussion of autonomy within the architectural profession. This is not specific to site intentionally.

1 the strategy 2

intro.

1.2.1

the objective

To identify how an established community, and their existing architecture, might use new innovative architectural solutions, existing infrastructure and adapted solutions, over time, to adapt to the consequences of sea-level rise on their living environment.

1.2.2

the structure

This Structure refers to the diagram on the following page

- chapter **02** A Discussion in chapter two concerns the PROBLEM, climate
page 11 change and the resultant sea-level rise on coastal communities.
- chapter **03** The CONCEPT of Adaptability drives this research.
page 27 The CRITERIA created includes four dimensions that define the aims of adaptable urban development throughout the thesis; (1)
- chapter **04** resilience, (2) governance, (3) spontaneity, and (4) affordability.
page 51 The SETTING applies this research to a context. This chapter introduces planned adaption and the Literature Review. An overview of the selection of site and analysis of Kilbirnie, Wellington.
- chapter **05** The ANALYSIS is the design outcome of the thesis investigation.
page 77 The Analysis has two parts: The Timelines and the Case Studies.
- chapter **06** The timelines considers the 70-year timeframe this research
page 107 involves.
- chapter **07** The RESPONSE supports 'The Execution' with the Palette of
page 151 Solutions. The Palette of Solutions are a library of urban and architectural design ideas that can be deployed incrementally to progress adaptable urban development. The criteria organises the solutions against their success of adaptability. The selection of design solution gives a choice to the stakeholder, depending on the intention of the response strategy. The Palette of Solutions created in this project can not only fortify the suburb of Kilbirnie, but instead, the intention is that it performs as a model that might be applied around the world in response to the specifics of a context. Reflection of these sections explain the design development and the process.
- chapter **08** The DESIGN supports 'The Idea' to reiterate and progress. It
page 189 considers how qualities of 'The Execution' arrange to achieve adaptability. An iterative process explores these ideas.
- chapter **09** The HUB is a vision of the future of coastal architecture, applied
page 205 to the context of Kilbirnie, Wellington. It proposes a series of design moves, which act as catalysts for adaptive urban development. 'The Hub' proposes floating architecture that functions as a circular economy, providing communal facilities for individual floating homes. It is presented as a physical model to communicate a sense of imagination and possibility.

Fig. 1.01.

problem

The primary objective of this research portfolio is to develop a guide that outlines how architecture can respond to sea-level rise. The context investigates urban residential communities where standalone and mid-rise housing typologies are primary, targeting low or middle income communities. Generally, a multi-disciplinary, research-led design process is followed. It is rigorous and iterative and applies both research and design methods.

concept

The basis of the research is presenting the problem of climate change, in particular sea-level rise, and the real risks associated. It is designed from a context review of preventative flooding and sea-level rise urban and architectural solutions, with reference to literature and case studies. The initial research method explores how literature and case studies can provide strategic direction to this research. The strategy then focuses on creating a holistic representation of these learnings through integrating key literature into a criteria model.

criteria

With the desire to critique the case studies that had been studied, the design method of the Palette of Solutions was created. This design component generates a visual representation of the opportunities available to designing for flooding and sea-level rise. The criteria provide an analysis of the Palette of Solutions whilst acknowledging the context of setting; Kilbirnie.

analysis

After a process of reviewing, engaging and applying the framework, the design outcome of the framework is interrogated. A critical reflection of

the research identifies suitable design solutions. These findings are tested through shifting scales from an individual response to a neighbourhood exercise. Design iterations were used as a tool to produce the idea. This scale changes as the speculation of the timeline occurs. Seven timelines have been identified as a possibility within the 70 year timeframe of this research.

The framework and findings are evaluated and developed into The Hub. ‘Lapping at the edges’ aims to be both accessible to architectural professionals, providing some simple strategies to enhance the living environments that are to be at risk, and informative, offering a conceptual approach to designing for water-related climate change hazards. ‘The Hub’ is an example of how the Palette of Solutions can be applied to one context, Kilbirnie, given the projected future timelines. Adaptability of a system is reflected in the ability to fit a new situation. Therefore, the research and design methods create an initial guide of how to respond to flooding and sea-level rise, and the design outcome is a representation of one option.

Critical reflection is important throughout the development of the research. In particular, phase planning is vital to investigate the severity of the problem and determine when mitigation strategies have to change to survival strategies. Engaging with the public will be crucial on the issue of sea-level rise and, in particular, the associated lifestyle and environmental changes it will cause.

response

design

the hub

THE PROBLEM

2.1 Climate Change	12
2.2 Sea Level Rise	16
2.3 New Zealand	20
2.4 Summary: The problem	25

prob
lem.

climate change

Global warming is an increasingly relevant risk across the globe. The warming associated with anthropogenic emissions (including greenhouse gases, aerosols and their precursors) from the base rate of the pre-industrial period (the multi-century period prior to the onset of large-scale industrial activity around 1750). "The reference period 1850-1900 is used to approximate pre-industrial GMST" continues to cause further long-term changes in the climate system, such as melting of the ice-sheets, intensified weather events or sea-level rise and the associated risks and impacts (Masson-Delmotte, 2018).

Human activities have caused an

increase of approximately 1.0°C above the pre-industrial levels, and Masson-Delmotte (2018) theorise that "global warming is likely to reach 1.5°C between 2030 and 2052 if contributing human activities continue to increase at the current rate (high confidence)". Estimations of global temperature increase and other climate system changes vary due to the magnitude and rate of warming, geographic location, development level and vulnerability of the system, and on the choices and implementation of adaptation and mitigation options (Masson-Delmotte, 2018). Even if we can maintain only a 2°C rise in temperature, as per the Paris agreement, projections suggest the

severity of sea-level rise and the impact of flooding still becomes heightened between 1.5°C and 2.0°C of warming.

Scientific projections suggest that dramatic climatic differences are expected if we aren't able to mitigate warming below 1.5°C (Bell et al., 2017; Masson-Delmotte, 2018). These differences include increases in the mean temperature of land and ocean, extreme heat waves, an increase in heavy precipitation and flooding in some regions and, conversely, the likelihood of drought and precipitation deficiencies in other regions (Masson-Delmotte, 2018). An increase in temperature indicates an increase in the atmosphere's capacity to store water, which reinforces the theory that human-influenced global-warming is partially responsible for increases in heavy precipitation (Min et al., 2011). A combination of observations, model to model comparisons and modelling were completed by Min et al. (2011) to research human-induced behaviour and its climatic effects. The research concluded "increases in greenhouse

gases have contributed to the observed intensification of heavy precipitation events found over approximately two-thirds of data-covered parts of the Northern Hemisphere land areas". These findings, when considered in the context of New Zealand, are a great cause for concern as extreme rainfall is already the most common cause of flooding in New Zealand (Adeyeye & Emmitt, 2017; Ministry for the Environment, n.d.-b).

The ocean is a long-term indicator of the effects of global warming, such as temperature change, carbon emissions, and increase in sea-level. Masson-Delmotte (2018) report that the ocean has absorbed around 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification (Masson-Delmotte, 2018). The present report focuses primarily on the current and impending impacts of sea-level rise.

Diagram of the contributors and impacts of Climate Change
Fig. 2.01.

“The total population exposed to flooding could triple to 150 million by the 2070’s due to sea-level rise and increased occurrence of storms, subsidence, population growth and urbanisation”
- (Adeyeye, 2017)

sea-level rise

More and more people occupy the coastlines, or have access to water, whether this be the sea or river. A lot of the most prosperous cities across the globe are by water; Tokyo, New York, London, Shanghai, Mumbai and Sydney as water provided access to trading, and hence, economic and population growth have always occurred. The total population exposed to flooding could triple to 150 million by the 2070's due to sea-level rise and increased occurrence of storms, subsidence, population growth and urbanisation (Adeyeye & Emmitt,

2017). Barredo, (2007) claimed that even without climate change, there would still have been an increase of foreseeable flooding in Europe. He claims this increased flood vulnerability in Europe is accredited to excess population and income, forcing the move to flood-prone land. This higher income escalates the living expectations, removing the chance of natural drainage to cater for more impervious surfaces. Therefore, the issue of sea-level rise are at their maximum as both scenarios are valid (Barredo, 2007).

2.2.1 Sea-Level Rise Measurement Types:

There are three types of measurement for sea-level rise, which refer to different scales; absolute (or eustatic), offsets (or departures) and local (or relative).

1. Absolute or eustatic rise in ocean levels, measures relative to the centre of the Earth via satellite. This form of measurement expresses the global mean for sea-level rise projections.

2. Considerations of the regional offsets from the global mean is necessary. Significant variation can occur in response to warming and wind patterns between different regional seas. New Zealand seas differ from other regions, due to their location nearer to the South Pole, and the El Nino and El Nina weather events, and hence this offset is applicable.

3. Local or relative sea-level rise considers the local land vertical movement, in addition to the regional sea-level rise. Tide gauges acquire local measurements. This measurement provides a record of relative sea-level rise that is needed to adapt to locally. Local subsidence exacerbating the sea-level rise locally, is occurring in the lower North Island (from co-seismic slow-slip events). Therefore, this scale of measurement provides greater detail, which is beneficial for the

planning of adapting to sea-level rise (Bell et al., 2017).

2.2.2 Contributors to sea-level rise:

Sea-level rise is a lagged representation of the effects of rising temperatures. Two main processes link rising atmospheric temperature and sea-level change: volume increase and mass increase. Firstly, as ocean water temperature increase, the volume of the water expands slightly, an effect which is cumulative over the entire depth of the ocean. This expansion is generally converted to a height increase, as the coastline is largely constrained (despite the inundation of low-lying areas). Secondly, melting of the land-based volumes of water have increased the mass of the ocean, decreasing the freshwater supplies available. This increase includes the melting of glaciers and ice sheets, as these ice stores diminish and increase the surface and ocean temperatures (Bell et al., 2017).

2.2.3 Key impacts of the rising sea-levels are:

1. Regular inundation of low-lying areas, creating increased marsh areas and adjoining dry land on spring tides.
2. Increase in the frequency of extreme weather events, damaging

resilience infrastructure.

3. The increased erosion of sand and gravel along shorelines and unconsolidated cliffs (unless sediment increases).
4. Increased invasion of saltwater into nearby groundwater aquifers, increases the salinity levels in soil and freshwaters and raises the freshwater tables, affecting the tidally influenced groundwater systems.
5. Increased high tide levels creating incursion for lowland rivers, creating flooding possibilities further up (Bell et al., 2017).

Historic readings of sea-level are not appropriate to use as indicators for future scenarios. Ocean and ice environments provide a delayed and non-linear response; therefore, consideration of natural variability and uncertainty of global emission levels. Future projections must provide a range of global emission rates, using scientific data to detect the vulnerability of a system, its potential collapse and the respective consequences. Planning and design purposes rely on these future projections (Bell et al., 2017).

2.2.4 Scientific projections:

Projection modelling has projected that mean sea-level rise suggest an indicative range of 0.26 to 0.77m by 2100 for 1.5°C of warming. Projections suggest that if global warming exceeds 2.0°C, sea-level

rise increases by a range of 0.1m. If this warming can be maintained to 1.5°C, and therefore reducing the mean sea-level rise by 0.1m, this implies the protection of 10 million people to the relative risk (based on the population in the year 2010 and assuming no adaptation) (Masson-Delmotte, 2018). The potential irreversible loss of Antarctica, and the Greenland ice sheets pose a severe threat to the rise of sea-levels. These instabilities could be triggered at 1.5°C and 2.0°C of global warming, causing a multi-meter rise in sea-levels (Masson-Delmotte, 2018). The projected future modelling of sea-level rise does not include the melting of these ice-sheets, and their instability poses an increased risk to the natural and human systems that are currently lacking. Projections suggest sea-levels continue to rise beyond the research timeline of 2100. Therefore, it is vital to slow the rate of warming, to reduce the rate of sea-level rise to enable more significant opportunities of adaptation in the natural and human systems that are affected, such as small islands, low lying coastal areas and deltas (Masson-Delmotte, 2018). Therefore, designing adaptive coastal solutions is exceptionally relevant right now. This research explores how a changing environment, specifically the sea-level rising, affects how we live and the architecture that we inhabit.

prob
lem.

new zealand

Increased global warming intensifies the exposure of small islands, low-lying areas and deltas to the risks associated with sea-level rise for many human and ecological systems. These include increased saltwater intrusion, flooding and damage to infrastructure.

New Zealand is an island country, assembled by two main landmasses, the North and South Island, and around 600 smaller islands. No location in New Zealand is more than 130km from the sea (Walrond, 2005). The coastline is 15, 134km in

length (Sen Nag, 2018). 80% of New Zealand's perimeter has exposure to the sea; harbours and estuaries provide shelter to the remaining 20% (Walrond, 2005). Therefore, a large area of New Zealand is susceptible to the associated risks of sea-level rise. Mitigating the increase of warming enables us greater opportunities to adapt, manage and restore the existing natural coastal environment and the reinforcement of vulnerable infrastructure (Masson-Delmotte, 2018).

The close comparison of global and New Zealand average historic rates means that the projections of future sea-level rise by the Intergovernmental Panel on Climate Change and other peer-reviewed sources, generated as global means, can generally be adopted for overall use in New Zealand. Small local adjustments for significant local vertical land movement may be needed, however, along with small increases in the projections for the south-west Pacific region (relative to the global mean projections) (Bell et al., 2017).

Hannah and Bell investigated local sea-level trends in 10 gauge sites (2012). When comparing locations, there is a noticeable spread of trends in local sea-level rise, of which Wellington presented the highest

example of 2.23mm/yr. (Bell et al., 2017)

The lower North Island is subsiding presently, on average at 1-3 mm/yr due to interseismic slow-slip activity (Beavan & Litchfield, 2012; Bell et al., 2017; Bell & Hannah, 2019; Houlié & Stern, 2017).

The rate of subsidence is not apparent, but analysis of the trend in the Wellington tide gauge record indicates the relative SLR increases noticeably after 1998, giving rise to a higher rate of local sea-level rise in the last decade or so (Bell & Hannah, 2019). Any significant long-term vertical land movement should be factored into local SLR projections, especially if the land is subsiding because this heightens the local net rise in sea-level, requiring adaption (Bell et al., 2017).

2.3.2

new zealand coastal cities

01. auckland

[population: 1,467,800]

02. wellington

[population: 420,000]

03. christchurch

[population: 400,000]

04. hamilton

[population: 240,000]

05. tauranga

[population: 141,600]

06. napier

[population: 134,500]

07. dunedin

[population: 122,000]

Fig. 2.02.

NZ average relative SLR (four main ports): 1.78 + or - 0.21 mm/yr

Auckland
1.60 mm/yr (+ or - 0.08)

Wellington
2.23 mm/yr (+ or - 0.16)

Lyttelton
2.12 mm/yr (+ or - 0.09)

Dunedin
1.42 mm/yr (+ or - 0.08)

[land subsidence] ↓
[land uplift] ↑
[no substantial movement] —

Fig. 2.03.

2.3.3

personal connection

This research is influenced by a personal connection to the coast, as I have grown up in the small coastal holiday town of Waihi Beach, located an hour north of Tauranga. The Bowentown peninsula is a reclaimed formed landmass, which is low-lying and already experiences drainage issues with flooding.

Currently, waterfront properties are considered desirable places to live and can be an expensive investment. However, climate scientists are already considering waterfront property an unsustainable long-term investment. "I don't think I would buy a shoreline property with the expectation that it's an investment that I would be passing down to my kids or grandkids," says Ian Miller, a coastal hazard scientist at the Washington Sea Grant (Knueven, 2019; Masson-Delmotte, 2018). An impending shift in mentality can be predicted; from the desire to live by the water to considering this a

risky and desperate investment. This change involves the economic market of waterfront property, influencing the relocation of wealth and hence, accommodating more impoverished communities within the vulnerable locations that are flood-prone or at risk of sea-level rise. "Countries in the tropics and Southern Hemisphere subtropics are projected to experience the largest impacts on economic growth due to climate change should global warming increase from 1.5°C to 2.0°C (medium confidence)" (Masson-Delmotte, 2018).

2.3.4

shift in mentality, waterfront property

To maintain and limit global warming to 1.5°C with no or limited overshoot, and options with higher overshoot model pathways require CO2 emissions to be reduced to net zero globally around 2050 (Masson-Delmotte, 2018). This is indicative of the urgent global challenge of climate change. Mitigation of the effects of climate change is vital, but

in parallel, the acknowledgement of the consequences is as essential. Preparing a response to these effects is necessary for reducing the harm to the affected living environments. Chapter Three explores the response strategies available to respond to sea-level rise by reviewing literature and urban planning case studies.

prob
lem.

summary: the problem

THE CONCEPT

ADAPTABILITY

3.1	<i>Response Strategies</i>	28
3.2	<i>Decentralising Water</i>	38
3.3	<i>Define: Adapt to water</i>	43

The following section explains what the design research addresses and the primary concepts that will be incorporated throughout.

con
cept.

3 1 response strategies

Sea-level rise and the respective flooding have exposed the vulnerability within the context of New Zealand with the relevant research. These climate changes influence millions of people living in coastal areas all over the world. There are three alternatives to responding to the encroaching water: defending against, using engineering solutions and

extensive infrastructure to protect a place; relocating people and resources living near water to higher ground, avoiding the risk of the coast. Finally, adapting to this changing context, learning to live with the encroaching water by providing permeable and ecological areas to allow the fluctuation of water around significant infrastructure.

01 defend

[keep water out]

Fig. 3.01.

02 surrender

[move to higher ground]

Fig. 3.02.

03 engage

[live with water]

Fig. 3.03.

3.1.1

In developed countries engineering solutions and structural measures are the existing primary method to flood management. This infrastructure aligns with the attitude of

defence against flooding as opposed to the adaptation to flooding. Urbanisation means we are continually looking for suitable space to inhabit.

These approaches use physical barriers which prevent water from intruding beyond a certain level (van der Nat et al., 2016). These structural measures that provide defence against flooding can include dykes (levees), polders, dams, floodwalls, surge barriers, pumps, reservoirs, or measures to improve infiltration of rainfall into the soil (Hansson et al., 2008). The Netherlands is an ‘artificial country’ (Olthius, 2012) as a large proportion of the country’s land lies below sea-level, and many large European rivers make their way to the ocean. Rijkswaterstaat manages the civil and water infrastructure in the country, providing vital flood protection. The water management system includes 3700 kilometres of flood defences and involves both natural defences, such as dunes but also an extensive network of engineering solutions. The primary defences for the Netherlands are the Delta Works which consists of three locks, six dams and five storm surge barriers. Despite the recent

shift in policy towards the ‘Living with Water Programme’ the existing system currently relies heavily on structural, hard engineering defences. The storm surge barriers protect against high water levels, and can be moved into place to maintain a lower water level behind the barrier, meaning the dykes behind them don’t have to be as high. Each of the five dykes are technically structures that function exclusively for their location. For example, sluices which can close at the press of a button, dry docks which fill and allow the barrier on each side to float and rotate and meet the other where they then fill with water and sink, or inflatable rubber barriers which fill with air and water (Rijkswaterstaat, n.d.-b). Rijkswaterstaat current strategy of the Delta Programme considers to be sufficient until at least 2050, identifying the importance to invest in knowledge now to form adaptive strategies and flexible measure to make it possible to respond in the future (Rijkswaterstaat, n.d.-a).

3.1.2

The Dutch have to always defend against water, as the land lies below sea-level. A program that is being initiated by the Dutch Government is the Live with Water Programme, which is encouraging the adaptive response method. The programme must also continue to maintain and benefit the existing defensive engineering network. The Room for the River project is part of the Live with Water Programme.

It combines defensive dyke systems, the relocation of homes and the repurchase of land, into adaptable programs providing a productive solution. This comparison of cases and their respective outcomes highlight the desperation of the Netherlands situation, where New Zealand has higher land to relocate to, and fewer people to relocate.

Fig. 3.04.

Fig. 3.05.

Fig. 3.06.

before and after:
room voor the rivier

room voor de rivier, the netherlands

Fig. 3.07.

whanganui, new zealand

Fig. 3.08.

3.1.4

The Dutch government initiated the Ruimte voor de Rivier ("Room for the River") program which aims to expand the capacity of the rivers' throughout the Netherlands in extreme storm events. In Nijmegen, the river bends sharply to the west which forms a bottleneck in the river. Relocation of the dyke allows the addition of an ancillary channel providing an adequate reduction of flooding. This master plan maintains the existing landscape with the formation of an island, the Spiegelwaal (Mirror Walloon) (INNOVA Ezine, 2018). The result is a unique urban river park available

for recreational and cultural activities (Ruimte voor de Waal, 2014). This excavation work was completed in March 2016 and reduced the water level of the Waal River by up to 35cm (Ruimte voor de Rivier, n.d.). The new island has attracted development and the opportunity for residents to improve their connection with the water. Three new bridges have maintained the access between Nijmegen and Lent and allowed for 25,000 homes to be built (Baca Architects, 2016). Displaced land and homeowners received compensation from the government (Aiken et al., 2014).

3.1.5

The town of Whanganui has a similar landscape and flooding situation to that of the Ruimte voor de Rivier project. The increased volume paired with the bend in the river creates a 'bottleneck', causing flooding

every year. With a similar landscape, applying a parallel design from the Room to River project to Whanganui could mitigate the risk of the flooding situation.

con
cept.

decentralising water

Office of Metropolitan Architecture (OMA) is an international practice which design the Urban Water strategy for New Jersey (OMA, 2013). The US Department of Housing and Urban Development requested The Urban Water Strategy for the Hurricane Sandy Rebuilding

Task Force. The project began in 2013 and is ongoing. OMA's resiliency masterplan is the recipient of the 2016 Smart Growth Award. This research is interested in the comprehensive Urban Water Strategy because they have categorised this programme with four areas;

1. Resist – Programmed hard infrastructure and soft landscape for coastal defence.
2. Delay – Policy Recommendations, guidelines and urban infrastructure to slow rainwater runoff;
3. Store- A circuit of interconnected green infrastructure to store and direct excess rainwater; and
4. Discharge – Water pumps and alternative routes to support drainage.

The responsive strategies of defending, surrender and engage are categorised into one stage. Government interaction of policy recommendations and guidelines are acknowledged. This approach differs as it recognises the timeline of flooding; firstly resisting it at the coast, delaying it affecting the

significant infrastructure, hence, storing it in appropriate areas and finally, the discharge of the water. This timeline is essential at acknowledging responsive planning for flooding and sea-level rise. The focus needs to alter according to the stage that is occurring. These infrastructural solutions are discussed by Adeyeye and Emmitt (2017) who suggest the combined implementation of both mitigation and adaptation strategies to reduce long term impacts and protect from sudden and immediate hazards or events. The most effective method is not any individual infrastructural approach but rather the implementation of more collaborative approaches, the integration of natural cycles with human-made landscape and developments through planning.

3.2.1

combining response strategies

BIG U

Brooklyn, NY

Image Redacted due to copyright

Hurricane Sandy hit New York City in 2012. It destroyed significant infrastructure and showcased the immense vulnerability of the city. Five billion dollars contributed to updating the preventive measures of Lower Manhattan. The design creates a landscape buffer that also includes focus on utilising infrastructure for the formation of public space. The Dryline which was created by a team that includes the Danish architect's form BIG and Dutch studio One Architecture & Urbanism, was awarded the Global Holcim Bronze Award in 2015. The design achieves technical ideas, delivered through flood protection that double as social infrastructure. It encompasses a 12-kilometre perimeter of coastline, which supports half a million residents and workers. The design strategies created in this project can not only fortify the city of New York, but additionally act as a model to be applied across the world (Lafarge Holcim Foundation, 2015; Lafarge Holcim Foundation2, 2015). The Dryline's various components have become a catalogue of adaptive strategies and replicable prototypes (Lafarge Holcim Foundation3, 2014). These components provide additional content for the Palette of Solutions

being developed in this thesis.

This design included participatory design sessions involving the team, residents, and more than 25 disaster preparedness groups. These discussions identified new opportunities for public participation, promenades, and spaces of activity (courts and table tennis tables) and learning. Protective walls wrapped with artwork deploys in emergency storm events from the ceiling serving as a floodwater barrier. Concrete elements provide a water barrier, and depending on the form double as park benches, planters, seating at playing fields, bicycle shelters or skateboard ramps. These embankments provide additional green areas within the urban design, while also dampening nearby traffic noise and providing elevated access ways, bridging the FDR Drive (parkway that runs along the coast) and raising areas of the 12km cycle path. Designing to reduce the risk that water poses too significant infrastructure, prioritising these vital access routes within the city (Lafarge Holcim Foundation, 2015; Lafarge Holcim Foundation2, 2015).

3.2.2

dryline, lower manhattan BIG & others

This literature review and case study analysis investigates how these three methods compare and combine. However, for this research project, I am interested in how societies can react to this changing environment and adapt accordingly. Engaging the responsive method of adaption aligns with the motive of this design, achieved through the process and outcome.

This research is especially interested in these adaptable solutions, and how we can change our mentality from keeping water out to living with water. To achieve the most effective

result, a combination of all response strategies; defend, relocate and adapt should be used. Combining these response strategies is the most efficient way to reduce the vulnerability of the people living in affected coastal areas. Defensive and Relocation response strategies are logical or required in some scenarios, and if this infrastructure exists, then it should be utilised. The Dryline project successfully combines these strategies through the application of urban infrastructure. The project has produced man-made forms, shaped organically, that act as a defence line along the coast.

adapt to water

The term adaptability is used regularly throughout this thesis and frequently within design literature. The Architectural profession uses words such as dynamic, resilient, and sustainable to glorify a design. These terms can often lack precise definition and are used to exaggerate the quality and breadth of a project. This is reflective of the wider issue in architecture, that there is no universal scale to compare the adaptability of a project.

In 'Resilience Thinking: Sustaining Ecosystems and People in a Changing World' (2012), Walker

and Salt define adaptability as "the capacity of actors in a system (people) to manage resilience. This might be to avoid crossing into an undesirable system regime, or to succeed in crossing into a desirable one' (Walker & Salt, 2012). Adaptability, by Walker and Salt (2012) has established the definition for this selected research.

Literature-based theories will provide the definition of adapt, and further the depth and context of the interconnected nature of adaptability and resilience in Chapter Four.

3.3.0

types of adaptability

“Adaption and mitigation are already occurring (high confidence). Future climate-related risks would be reduced by the upscaling and acceleration of far-reaching, multi-level and cross-sectoral mitigation, by both incremental and transformational adaptation (high confidence) (Masson-Delmotte, 2018).”

I have identified two types of adaption: planned time responsive adaption and spontaneous adaption. Research-based assumptions, combined with a forecasted range of possibilities, allows phase planning to react over a timeframe. The phases accommodate the potential threats and diversions to allow

for every situation. This method is responsive to the continually changing issue of sea-level rise.

Sea-level rise represents a long-term dynamic risk. 90% of the energy added to the climate system ends up in the oceans; hence, rising sea-levels are a great indicator that the Earth is warming (Bell et al., 2017; Rhein & Rintoul, 2013).

The other method is spontaneous adaption, which considers a shorter time frame, where quick reactions are necessary. Spontaneous adaptability is necessary to adapt to sea-level rise to respond to freak weather events and unforeseen factors.

etymo
logy.

3.3.2

definition.

(2012) ▾
WALKER & SALT

a d a p t

[verb]

In 'Resilience Thinking: Sustaining Ecosystems and People in a Changing World', Walker and Salt define adaptability as "the capacity of actors in a system (people) to manage resilience. This might be to avoid crossing into an undesirable system regime, or to succeed in crossing into a desirable one' (Walker and Salt, 2012).

wor
ds.

3.3.2
===
definition.

**[The capacity for people
and architecture to
manage resilience]**

**[removes certainty, takes
away the comfortable
everyday routine]**

[The long-term forecast,
with projected phases of
change]

**planned
adaption**

**spontaneous
adaption**

[Unexpected short-term
disturbances that require
instant action]

Fig. 3.11.
Diagram of Types of Adaptability

THE CRITERIA

4.1	Theories: Adaptability	52
4.2	Built Environment	61
4.3	Development of the Criteria	65
4.4	The Adaptability Criteria	69

crit
eria.

4 theories: adaptability

The word adaptability is the key driver for this research. It became apparent that there was a lack of connection between the thinking and application, as the literature sourced for this research was not influencing the production of the design. Hence, the criteria of adaptability was necessary to analyse the case study analysis and Palette of solutions. The criteria needed to be

measurable to compare and test the success of each component to inform design decisions in the future of the research process. This section considers literature-based theories, which present ideas on how to adapt. These definitions influence the overall understanding of adaptability, and the creation of this criteria for this research.

Literature-based theories inform the symbiotic relationship between the living environment and how it can be adaptive. An understanding of how natural ecosystems function is necessary for this research. Social-Ecological systems explain how the human and natural ecosystems are linked, and hence, how climate change and sea-level rise are affecting the instabilities between these two ecosystems. The theory of Panarchy explains that nature is constantly evolving and unpredictable, identifying the requirements of adaptive

changes, and how this applies to an ecosystem. It highlights the connection of resilience to adaptability and defines resilience for the remaining research. The Adaptive Cycle examines how ecosystems generally process. Four phases detail this: rapid growth, conservation, release and reorganisation. Finally, evaluation that the selected theories must function as an open system to enhance their adaptability. Open systems are evident within the living and built environment, and showcase the flexibility of a community.

theories

“The human and natural world are inextricably linked,” said Gunderson and Holling, (2002) and social-ecological systems are the created term that describes this discovery. It assumes that ecological and human systems could be managed by individual components, through finding a balance between the supply and demand. It anticipated that the system would remain consistent throughout this time. However, these assumptions are not accurate when applied to the interacting systems of human and nature (social-ecological systems) as they are dynamic and continuously changing. The previous year provides no suggestion of how the system might perform in the next annual forecast. “The structure and function of the systems continually change through time (and continue

to change even more rapidly in the future as global warming becomes an ever-stronger driver of change)” (Walker & Salt, 2012).

A rising population overall, and specifically in our urban areas is causing our planet to warm. This population increase causes consequences within the existing social-ecological ecosystems as they are evolving. The second chapter, the Problem, explains in greater depth the connected systems which are affected by this warming. Unsustainable development of the existing social-ecological networks causes disturbances, for example, climate change. This unsustainable development can be grouped into three categories:

1. there is no choice but to overuse the specific resource;
2. the depletion is completed wilfully

and often greedily, and lastly, 3. the misunderstanding through the application of inappropriate models that don’t accurately represent how the world’s systems function.

The first category, where there is no choice but to use up the local resource, is generally associated with large populations that are experiencing poverty. In these situations, survival is dependant on these resources. Producing more or other resources are the only option, and this is apparent in the vernacular communities. Their livelihoods and architecture is generated and relies solely on the resources that the local social-ecological systems can produce (Walker & Salt, 2012). These resources inform the vernacular urbanism of each community. There

is a direct correlation between the everyday life of the place; particular habits, social connections and hierarchies, along with technology and local materials. Maximising these particular habits by harnessing energy from the natural environment increases the resilience and affordability of a social-ecological system. These architectures are the constructed outcomes of the practice of everyday life. There is an admirable accuracy and precision in the translation of actions into things, needs into objects (Ramírez-Lovering, 2008). The theories of the Panarchy, Adaptive Cycle and Open Systems utilise the term social-ecological ecosystems throughout; hence, making it a valuable theory that provides context.

In Panarchy, Holling and Gunderson (2002) present the idea that nature is evolving and discuss the development of theories for a sustainable future. "Ecosystems are moving targets, with multiple futures that are uncertain and unpredictable. Therefore, management has to be flexible, adaptive, and experimental at scales compatible with the scales of critical ecosystem functions" (Gunderson et al., 1995; Walters, 1986).

Panarchy identifies three requirements for the theory of adaptive change:

1. First, the system must be productive, must acquire resources and accumulate them, not for the present, but for the potential they offer for the future.
2. Second, in the face of significant disturbances, variables can shift and move, maintaining the systems control and structure. Reflection of the degree and intensity of internal controls, compared to the influence of external variability. The consequences of a highly resilient system is that the system cannot change in any fundamental way. An interplay between stabilising and destabilising properties is at the core of present issues of development

and the environment – global change, biodiversity loss, ecosystem restoration, and sustainable development.

3. Third, somehow the resilience of the system must be a dynamic and changing quantity that generates and sustains both options and novelty, providing a shifting balance between vulnerability and persistence.

The quote from Walker and Salt illustrates the connection between resilience and adaptability of a system: "the capacity of actors in a system (people) to manage resilience". This might be to avoid crossing into an undesirable system regime, or to succeed in crossing into a desirable one. The two terms are interconnected, and the system must acquire both adaptability and resilience to succeed. Therefore, resilience is essential to an adaptable system. Both books, Panarchy by Holling and Gunderson (2002) and resilience Thinking by Walker and Salt (2012) investigate the term of resilience. Panarchy divides resilience into two terms, engineering resilience and ecological resilience.

Engineering resilience is a more traditional model, which focuses on

the efficiency of function, control, constancy, and predictability. Engineering resilience concentrates on stability near an equilibrium steady state, which desires fail-safe design with optimal performance. This form is appropriate for systems where uncertainty is low, and resistance to disturbance and speed of return to the equilibrium measure the worth. Engineering resilience is counterproductive for systems which are high in uncertainty, as they are required to respond to a dynamic and evolving environment. The second definition of resilience is therefore required; focusing on persistence, adaptiveness, variability, and unpredictability. Defined as ecological resilience, all of these attributes embrace the evolutionary perspective, which promotes designing for sustainability. It removes the idea of the equilibrium state. It instead prioritises the stability of existence of function as "instabilities can flip a system into another regime of behaviour - i.e. to another stability domain" (Crawford S Holling, 1973). This definition measures "the magnitude of disturbance that can be absorbed before the system changes its structures by changing the variables and processes that

control behaviour" (Gunderson & Holling, 2002). The research focuses on ecological resilience.

The challenge of ecological resilience is conserving the ability to adapt to change, to respond with flexibility to uncertain situations and surprises that open opportunity. This capacity of evolution maintains the options to buffer disturbances and create novelty. "A living system cannot be kept within some desirable state or on some desirable trajectory if adaptive capacity is continuously lost" (Gunderson & Holling, 2002). Disturbances buffer at all scales: mangroves and dunes protect from storm surges at an urban scale, and the design of a water square can increase the resilience of a developed area.

Panarchy highlights the relevance of resilience within a system. The definition of ecological resilience has informed the understanding of this research. It identifies that resilience is not the only factor, as adaptability of a system is more complicated than that. Excess resilience of a system can cause failure, requiring a balance. Maximum adaptability can be obtained by employing natural systems.

The Adaptive Cycle, following the Panarchy theory, provides greater detail of how systems change; move through different phases, cycles and scales. “Why do we allow something of value to degrade to a level that will impact human welfare?” (Walker & Salt, 2012). Crossing a threshold into a regime in which the control (feedbacks) are different, makes it difficult for an ecosystem to regain stability or change to meet the new environment. Globally, the climate is changing, and we are beginning to enter a new threshold, and our response determines the failure or success of our ecosystem. The adaptive cycle, created by Gunderson and Holling (2002) describes how an ecosystem organises itself and responds to a changing world. The adaptive cycle provides an understanding of how globally we can still sustain a successful social-ecological system which provides for us. Identifying which phase we are in allows the world globally to react to this to create balance and durability of a socio-ecological system. “The human and natural worlds are inextricably linked” (Gunderson & Holling, 2002). Globally natural ecosystems have been examined and generally process through recurring cycles comprised of four phases: rapid growth, conservation, release and reorganisation (fig. 4.01) (C.S

Holling & Gunderson, 2002).

Exploitation / Rapid growth (r): Resources are readily available; promoting innovation to exploit opportunities.

Conservation (K): Resources become increasingly unobtainable, the system begins to lock up, losing flexibility and the ability to respond to disturbances.

Release (Ω): Lack of response to a disturbance to the system, causing the unravelling of the system, releasing resources.

Reorganisation (a): New actors and ideas are required, and these innovations determine the success of the system, generally promoting the exploitation phase again, but can also lead to the collapse of the system.

The development of the system occurs throughout the exploitation and rapid growth phase (r), which merges into the conservation phase (K). This process is generally a slow accumulation of capital and stability and is reasonably predictable. As the conservation phase continues, the systems become progressively less flexible and resilient to external factors. Eventually, this causes a collapse of the system, responded by the release phase (Ω), which quickly develops to reorganisation (a). The reinvention allows experimentation of the system to occur. This back

loop either produces the initiation of the downfall (fig 4.03 (move 4)) or creative change of the system. An adaptive response is necessary to bounce back from this collapse and begin the fore loop of rapid growth once again (Walker et al., 2004; Walker & Salt, 2012).

The Adaptive cycle can be simply represented (fig. 4.02). Many variations exist within social-ecological systems, and this adaptive cycle is in no way fixed, with the ability to skip certain phases. The diagram (fig. 4.03) showcases how adaptive cycles can respond differently:

1. The rapid growth or exploitation phase would generally continue through to the conservation phase, or directly to the release phase.
2. The Conservation phase can move back to the growth phase.
3. If well managed, (of

ecosystems or organisations) the release phase can be stalled by creating an intervention at the smaller scales of the release and reorganisation phases, therefore preventing the development of the concern within the system (Walker & Salt, 2012).

The manner of response within each phase is individual to each system. The strength of the system highlights the flexibility and resilience of its behaviour between phases (Walker & Salt, 2012).

The Adaptive Cycle is relevant as it identifies the different stages. This theory is implemented within this research by the selection of the response strategies. This theory also identifies that resilience is a crucial component of adaptability, reiterating the admittance as a factor to the adaptability criteria.

Fig. 4.01.

Fig. 4.02.

Fig. 4.03.

Analysis of the adaptive cycle highlights the importance that any social-ecological system must function as an open-system. This concept presents one interconnected system, rather than a collection of individual components. "Open systems have the ability to expand and contract in response to changing conditions, and are inherently flexible" (Ramírez-Lovering, 2008). Open systems often develop from an informal situation, as their transient, flexible character allows each activity to 'fill the slack' within the urban fabric as space becomes available and demand changes. These versatile areas often integrate the formal and informal urban systems, forming diverse multi-use activities which can be replicated elsewhere, producing a catalyst for growth, or just as quickly shut down.

The un-regulated nature of these informal spaces have benefits to the character of the city. However, that is not without the attempt of these spaces to be removed from the developing world. Occasionally these informal developments become formalised through governmental regulations or intervention, but if not, they can present as a rebellion to the government. The governance surrounding these open systems can determine their flexibility. Open Systems highlights the strength of informality in a system. This theory identifies spontaneity as a critical component of adaptability, which is included as a factor. Floodable parks, living shorelines and bio-swaes all provide spontaneity within design, as water is allowed to fluctuate in and out of these zones.

The three theories cover different scales of social-ecological systems: Open Systems consider a wider urban environment, explained by the architecture of informality. It presents a large-scale approach which can expand and contract to the desired need or demand, allowing these systems to fill in-between the static built environment. Panarchy and the Adaptive Cycle provide legibility and structure to a dynamic system, providing greater understanding to a complex system.

These theories can be applied at multiple scales, e.g. an organisation or a landscape. It considers the collapse of an internal component of the system, whereas Open Systems consider external factors. Therefore, the Adaptive Cycle model is beneficial for understanding the process each element of a system is experiencing. It suggests that if a system is to develop, it needs to be dynamic and continually evolving, rejecting inertia and encouraging malleability.

crit
eria.

4 built environment

4.1.5

reflection

This model was created by Brand and showcases the different rates of deterioration of a building. The 'Shearing Layers of Change' separates a building into 6 layers of flexibility; from which 'site is eternal', Structure, Skin, Services, Space Plan and lastly, to the most mobile of objects, Stuff (fig. 4.04). This model is constructive in highlighting how often a building is changing and how this often affects particular 'layers' more than others. This literature presented some useful design ideas that have

provided additional resources to the architectural Palette of Solutions. The model presents financial concentration and durability in the structure, with variations possible at the skin, services, space plan and stuff layer. It suggests columns, simple roof forms and lastly, to be square in shape to reduce the need for change (Brand, 1995; Olthius, 2012).

Brand describes site as "this is the geographical setting, the urban location, and the legally defined

4.2.1

shearing layers

lot, whose boundaries and context outlast generations of ephemeral buildings. Site is 'eternal,'. It must consider that site is also changing. Climate change research has identified a long-term transformation occurring, land subsidence and sea-level rise are affecting how coastal sites are inhabited. The scale of this model maintains the correct order and timeline of change; however, this model does not consider the impacts of sea-level rise and the changing site, which is necessary to allow for adaption.

Shearing Layers highlights the layers of the built environment and

their specific levels of resilience and flexibility. Adaptability within these layers increase with their affordability, efficient design and materiality. Affordability is selected as an adaptability factor. Affordability within design look like modular, open plan living that maximises the natural environment with passive design techniques and material selection. This factor does not just acknowledge the economical affordability of a design, but also the social affordability. An adaptable system is only successful when encouragement of the culture to thrive through social interactions.

Fig. 4.04.

4.2.2

koen olthius, city apps

Why do we continue to build static infrastructure within a dynamic environment? Asks Koen Olthuis at the TED conference in Warwick (2012). We continue to build how we built 500 years ago; the building's we as architect's design only have to achieve a lifespan of 50 years, which use static components within a static city grid when we live within a dynamic economic, social, demographic and ecological environment.

Olthius suggests a flexible, dynamic approach can achieve to satisfy the changing needs of our society and explains the idea of Floating City Apps. City Apps allows flexibility of infrastructure, as it can be rented by municipalities from developers and floated in as it is needed. This idea caters for both sides of the economic scale (Olthius, 2012).

City Apps concerns a larger scale of infrastructure and planning than Brand's Shearing Layers, which examines the building scale. This

static development is still present at the building scale also, meaning as the social demand changes, renovations continue to occur. Continuing with existing design and building processes are unsustainable, and increasing the transformability of this process benefits a dynamic society. This research endeavours to develop dynamic solutions that involve the built environment and its relationship to urban infrastructure, and how life can develop with this. Floating infrastructure increases the flexibility of the design. This employs the question of governance: How does floating infrastructure affect the regional District Plans and international understanding of ownership? Consideration of how governments respond to these innovative solutions determine the future living environment. The factor of governance considers how policy can encourage or restrict adaptability.

"At the heart of resilience, thinking is a very simple notion – things change – and to ignore or resist this change is to increase our vulnerability and forego emerging opportunities. In so doing, we limit our options" (Walker & Salt, 2012). The built environments requires the acknowledgement of change to identify itself as a flexible and dynamic social-ecological system. The continuation of the construction of buildings with a lifespan of 50 years does not respond to this effectively.

Design research explores adaptive

infrastructure, including innovation, flexibility, informality, modular and scaffold systems. Literature has provided insight into existing frameworks, and helped form a criteria for adaptable resolutions. The Case studies and Palette of Solutions analysis test the success and failures of the completed and conceptual designs worldwide against this criteria. The theory of Shearing Layers and the concept of City Apps influenced the selection of the architectural typologies to analyse, which effectively respond to flooding and sea-level rise.

crit
eria.

development of the criteria

This research adopts the term Adaptability at the centre of the framework. Specific characteristics of adaptability analyse how effectively a design responds to this framework. This design needs to be able to acknowledge the timeline of this research, and how the development of the design, current program and future requirements are all achievable.

This criterion is attained by a scale, presenting the adaptability of each design solution with a simple visual. This method has proven successful in the Sasaki Urban Design for Boston, Jade Yu'An Au Morris's thesis research project of the Cambodian village of Kompong Phluk (Au Morris, 2014) and in the report prepared for Wellington City Council by Tonkin & Taylor, 'Sea Level Rise Options Analysis'.

Fig. 4.05.

Fig. 4.06.

Fig. 4.07.

4.3.1 Adaptive Landscape Architecture

Jade Yu'An Au Morris created a framework for her thesis work; 'Adaptive Landscape Architecture'. She analysed the difference between sustainability and resilience and created a framework that evolved from this literature. Morris used a development of Hawk's sustainability model using the broad terms of social, cultural, economic and environment to analyse the design (Au Morris, 2014).

4.3.2 Sasaki Sea Change Urban Design Principles

The Sasaki Urban Design used a similar framework to explore design strategies applicable to Boston in response to the sea-level rise projected to affect the city. Their model compared the design against technical design variables such as 'lowest cost' and 'largest lifespan' to provide measure this set of components against one another (Sasaki, 2014; Walker & Salt, 2012).

4.3.3 Sea-Level Rise Options Analysis

The report 'Sea-Level Rise Options Analysis' by Tonkin & Taylor Ltd prepared for Wellington City Council utilises a 'spider diagram' to provide a visual summary of the balance of impacts across the four wellbeings (the four axes) and for each sea-level rise scenario (the coloured lines). The impacts of sea-level rise on Wellington is spatially variable, as this overview provides commentary concerning specific areas of interest. The scoring system uses '0' for a very low impact and '5' for a highly significant impact (Tonkin & Taylor Ltd, 2013). The spider web diagram compares the impacts of selected suburbs to highlight the diversity of each suburb in Wellington, and therefore conclude diverse strategies that apply for a specific case. The five scenarios are presented in this diagram to present how the impact is altered by changing sea-level rise (scenario). It visually presents a timeline.

4.3.4

reflection

All of these examples use the scaled model methodology to present a variety of solutions. However, there is no communication of how each band is measurable for each design element, allowing this model to remain vague and up for personal assumption. These models are successful in conveying visually how active each project or strategy is at responding within the collection. The scale quickly compares the

differences between each case study project and solution visually. Therefore, each term does not have a measurable unit that can be scaled. The diagram presents the effectiveness of 'adaptability' achieved, acting as a tool to link the literature to design elements through a visual demonstration. Application of this criterion is completed in a similar way, where it is analysed personally by me.

crit
eria.

adaptability criteria

Literature research has outlined criteria for adaptive thinking. Case study analysis aims to explore the success and failures of completed and conceptual design worldwide in response to this criteria. This assessment identifies which designs promote adaptability as a driver. The four factors (axes) are resilience, governance, spontaneity and affordability. The bands of the criteria represent a scoring system, whereby the centre represents '0' for low

demonstration and '5' for a highly significant demonstration of each factor of adaptability. Each factor is defined in the following section, including an explanation of how this relates to design research, including durability, innovation, flexibility, open systems and modularity. These are several key aspects within adaptive infrastructure, which are explored and tested through design research, and presented, finally, as a Palette of Solutions.

Resilience:

The planning involved to respond to a range of long-term forecasted options that anticipate these projected phases of change.

Resilience is described as “the distance to the threshold” (Walker & Salt, 2012).

Ecological Resilience promotes designing for sustainability. It removes the idea of the equilibrium state, instead prioritising the stability of existence of the function (Crawford S Holling, 1973). This definition “is measured by the magnitude of disturbance that can be absorbed before the system changes its structures by changing the variables and processes that control behaviour”

Governance:

How different scales of policy and strategic thinking can be applied to a situation to engage adaptability. The variety of scales refer to how governance applies to the individual, to a community, council or country.

“That shifts the management and policy emphasis from micro, command and control approaches to ones that set overall conditions to allow adaptive enterprises” (C.S Holling & Gunderson, 2002).

“A mix of adaptation and mitigation options to limit global warming to 1.5°C, implemented in a participatory and integrated manner, can enable rapid, systemic transitions in urban and rural areas (high confidence). These are most effective when aligned with economic and sustainable development, and when local and regional governments and decision-makers are supported by national governments (medium confidence)” (Masson-Delmotte, 2018).

Spontaneity:

“He [Rapoport] describes spontaneous settlements as “cultural landscapes” which represent the decision of many individuals over long periods of time, but which are notable for adding up to “recognizable wholes” (Kellert & Napier, 1995).

How quickly a system can react to an unexpected event. This spontaneity is seen frequently in the evolution of an ecosystem to gain from a new situation. Informal settlements and vernacular communities possess these qualities in the context of the built environment.

Adaptability is increased when a system can react instantly or spontaneously to an issue. Planned adaption can also include this flexibility.

Affordability:

Minimising economic and social restrictions. Mitigating the financial and emotional requirements of a design allows it to be accessible to a larger population, increasing adaptability.

The issue of affordability relating to coastal defences and water management is best exemplified by the Netherlands. The current cost of inland and coastal water management in the Netherlands is approximately 1000 million euro per year (equivalent to 0.2% of Dutch GDP). The estimated additional cost if responding to a 1 metre se-level rise in 100 years is another 1000 million euro per year (Tonkin & Taylor Ltd, 2013).

Fig. 4.08.

resilience

[noun]

“Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure” (Walker and Salt, 2012).

governance

[noun]

“The action or manner of governing a state, organisation, etc.

spontaneity

[noun]

“The quality of being natural rather than planned in advance”

affordability

[noun]

“Ability to be afforded; inexpensiveness”

Diagram communicating the relationship between the adaptability criteria produced in Chapter 04, and how the following research are connected.

Fig. 4.09.

THE SETTING

KILBIRNIE, WELLINGTON

5.1	<i>The Timeline</i>	78
5.2	<i>Literature Review</i>	86
5.3	<i>We are rising</i>	88
5.4	<i>Selection of site: Kilbirnie</i>	92

ana
lysis.

the timeline

5.1.1

planned adaptation

To reiterate, planned adaption; it involves structuring phases of change in response to a projected long-term forecast. As mentioned previously, 90% of the energy added to the climate system ends up in the oceans; hence, rising sea-levels are a great indicator that the Earth is warming (Bell et al., 2017; Rhein & Rintoul, 2013). Now considering this, it is vital to consider that sea-level rise is occurring at a slow pace,

that we can generally forecast the expected changes.

Climate change scenario projections provide a better understanding of how a wide range of possible futures might unfold, under a consistent set of assumptions and associated uncertainties. They cannot predict or forecast the future (Moss et al., 2010; Rhein & Rintoul, 2013). The range of possibilities

provides policymakers with a set of alternatives and a range of futures to consider (Stocker et al., 2013). Adaptive decision-support tools are required to address these issues when applied to sea-level rise as it is a long-term change, which generally has a significant adjustment period (Bell et al., 2017). "Limiting the risk from global warming of 1.5 degrees Celsius in the context of sustainable

development and poverty eradication implies system transitions that can be enabled by an increase of adaption and mitigation investments, policy instruments, the acceleration of technological innovation and behaviour changes (high confidence)" (Masson-Delmotte, 2018)

Fig. 5.01.

The sea-level response to warming of the Earth's climate systems makes it an integrated global indicator – 90 per cent of the energy added to the climate system ends up in the oceans (Rhein & Rintoul, 2013). Observed sea-level rise, however, needs to be interpreted in light of substantial lags (decades to millennia) in the ongoing response to warming of the oceans and melting of glaciers and ice sheets (Bell et al., 2017; Dangendorf et al., 2015; Stocker et al., 2013). Therefore, the adaptive planning has a long term commitment to this slowly changing environment of sea-level rise.

The primary climate driver for sea-level rise is global and regional surface temperature, which is strongly influenced by greenhouse gas emissions. With the greenhouse gases currently in the atmosphere and 90% of the heat stored in the ocean, the world is already committed to further temperature increases, and an ongoing lagged response to sea-level rise. This delayed response is mainly influenced by the polar ice sheets, which are likely to diminish over thousands of years making predicting their occurrence difficult. (Bell et al., 2017).

Regardless of how we improve the emissions, it is inevitable that sea-levels are rising. The Paris Agreement establishes a goal of maintaining a mean global warming to below 2°C, if not 1.5°C. As part of the negotiations for the 2015 Paris Agreement, these emission pledges are to be implemented within a 2030 time horizon. Policies of similar impact are to continue following 2030. The time horizon of 2030 will hence, be a significant point in identifying the scientific projection accuracy and rate of change that we are experiencing (Bell et al., 2017). Therefore, this has identified one of the timelines for this research.

The projected global mean SLR range for all RCPs is relatively tight for the nearer timeframe. Reliability of the projections decrease as the timeframe increases. Hence there is an ever-increasing range of plausible sea-levels as the timeframe extends (Bell et al., 2017). With this considered, I decided to add a third timeframe, located between 2030 and 2100. Mid-century (2050) has identified as a timeline. The reliability of the projections are higher closer to the current timeline as there are fewer uncertainties that have to be accounted for when calculating the mean sea-level rise.

Across all scenarios, there is a near certainty that by 2050 sea-level rise has increased between the range of 0.15-0.30m. The uncertainty increases into the century, depending on how the global emissions transpire (NIWA, 2017).

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report utilises a 'process-based model' for sea-level projections which only extend through to the end of the century, 2100. Review of 'The Coastal hazards and climate change: guidance for local government' has provided a detailed consideration of how the IPCC report can affect New Zealand. This report compares the IPCC projections with that of a 'probabilistic approach' of Kopp et al. (2014) (Bell et al., 2017) which extends out to a timeframe of 2200. The Kopp et al. model projections reasonably closely match the IPCC projections. These projections have been used internationally in adaptation assessments (Bell et al., 2017). As these projections are considered globally for the assessment of climate change, and accuracy declines over time, the final timeline for this research is 2100. This research, therefore, considers a timeline of 2030 till 2100 (70 year

period) which also aligns with the idea of considering how the context alters over an individual's lifetime. The Coastal hazards and climate change: guidance for local government report considers how the range of calculated potential outcomes can vary. "Hazard assessments, risk and vulnerability assessments and comprehensive adaptation plans require these SLR scenarios in determining decision points for response-option pathways and understanding the sensitivity to a range of sea-level futures at a locality" (Bell et al., 2017). Planning pathways need to allow time for adaptive planning to be implemented successfully in communities. Decision points determine adaptive pathways for communities over possible periods and adaptation thresholds. Bracketed timeframes are essential in determining when it is appropriate for asset and staging infrastructure projects (Bell et al., 2017).

The report provides decadal increments for projections of sea-level rise for the wider New Zealand region. With the selection of the three timeframes, the New Zealand sea-level rise scenario showcases how over the 70 years the warming can increase, hence, creating a

delayed response displayed by sea-level rise. I have identified the NZ RCP8.5 M as the selected projection scenario, which provides the following data:

2030: 0.15m
2050: 0.28m
2100: 0.79m

Comparing RCP emission scenarios with the pledges and current policies showcases the lowest RCP2.6 pathway (a probable threshold for the onset of ice sheet instabilities) is difficult for the global community to achieve. Impacts to the scenarios achievements rely on the uncertainty around the implementation of the ambitious Paris Agreement targets, particularly beyond the 2030 target (Bell et al., 2017; Magnan et al., 2016). The four scenarios that were explored in Chapter 5 of the Coastal Hazards and Climate Change Guidance out to 2150 for the seas surrounding New Zealand are all purposefully constructed to meet the requirements in the NZ Coastal

Policy Statement. This statement provides planning for the next 100 years, supporting developing and stress-testing dynamic adaptive pathways to provide long-term planning to prepare for adaptation for vulnerable coastal areas.

I have based this research in the scope of the NZ RCP8.5 median projections because it calculates a situation with continuing high emissions. New Zealand too, is currently tracking higher than the goal to reach the Paris agreement. I am selecting this scenario, as there is evidence that the sea-level surrounding wider New Zealand is likely to rise by 5-10% more than the global average (Bell et al., 2017). It also considers the possibility that greenhouse gas emissions are unable to be reduced to maintain global warming to 1.5 degrees by 2050. This scenario has also been chosen to provide the 'worst-case scenario' sea-level rise calculated mean height and hence, the design solution to respond to this.

Fig. 5.02.

Fig. 5.03.

ana
lysis.

literature review

Disaster continues to highlight the linkage between the building design and urban configuration that reveals a community's vulnerability to the impacts of extreme natural events (Geis, 2000). Human settlements in both the developed and developing world are affected by this flooding, as becoming more pressing with the advent of rapid urbanisation causing more people to live in flood-prone zones. "Flooding is also less geographically discriminatory and is experienced in both urban and rural areas, as well as in the global north or south" (Bankoff, 2001).

Chapter four analysed adaptable theories, of which Open Systems

were identified. "Open systems have the ability to expand and contract in response to changing conditions, and are inherently flexible" (Ramírez-Lovering, 2008). The un-regulated nature of these informal spaces have benefits to the character of the city as their transient, flexible character allows each activity to 'fill the slack' within the urban fabric. as space becomes available and demand changes. A community within a flood prone area functioning as an open system makes use as space becomes available and demand changes, as water fluctuates in and out. Diego Ramirez-Lovering analyses the city of Guadalajara in Opportunistic Urbanism, revealing

the informal practices responded more effectively and efficiently than that of formal activities. "As a result, many areas we studied revealed themselves as fleeting, transitory, engaged in a permanent process of transformation". Many deprived communities are forced to live in flood-prone land and have adapted accordingly to this environment to survive. As the risk of the guaranteed warmer climate create consequences of higher precipitation events, the flexible design of how poor societies have lived within this flood-prone environment becomes beneficial for Western societies. These vernacular communities with limited resources to prevent flooding have learnt to live with water and risk and may have much to teach about adapting to their environment.

The author has had the opportunity to live in the Netherlands and experience many different cultures. This discussion draws on this familiarity, as well as the research and observations of others. The Netherlands have recently altered their behaviour towards water and hence, the response strategy of mitigating flooding and sea-level rise from defending against water to living with it. This approach has been a focus within the literature review as it is the central point this research is hoping to highlight, to become more resilient, affordable,

and spontaneous in this changing environment. This literature review has identified three architectural typologies that respond to flood risk; floodable, stilted, and floating architecture. It is essential to compare cultures, and all scales of wealth as this can showcase different ways of thinking. The vernacular communities have been adapting to flooding for decades to centuries, whereas the modern developments provide alternatives in cities. This analysis provides knowledge of how vernacular principles apply to developed infrastructure, and which of the 3 architectural typologies might be executed successfully in New Zealand. These communities can teach us about living with water and managing this risk.

Open systems often develop from an informal situation, as their transient, flexible character allows each activity to 'fill the slack' within the urban fabric as space becomes available and demand changes. These versatile areas often integrate the formal and informal urban systems, forming diverse multi-use activities which can be replicated elsewhere, producing a catalyst for growth, or just as easily shut down. The un-regulated nature of these informal spaces have benefits to the character of the city.

setting.

we are rising

Resolving the effects of sea-level rise is linked to a reduction of our impacts on the environment by reducing greenhouse gas emissions. WCC adopted the Low Carbon Capital Strategy (WCC, 2016), which is a strategy to reduce the emissions of the city. However, the reduction of greenhouse gases is a global issue, and therefore, Wellington is partially responsible, but not in direct control. "Despite increasing global effects on global efforts to reduce carbon emissions, many commentators believe that some amount of sea-level rise is inevitable due to historical emissions" (Tonkin & Taylor Ltd, 2013).

Government has previously suggested for New Zealand Councils to accommodate a risk management approach, considering a 0.5m base value of sea-level rise by 2090 relative to the 1980 – 1999 average sea-levels, with 10cm additionally per decade thereafter. Ministry for the Environment recommends sea-level rise of 0.8m should be considered, along with their respective consequences. Planning beyond 0.8m is suggested to consider past 2100, and for low probability/high consequence considerations (Tonkin & Taylor Ltd, 2013).

Wellington City Council (WCC) recognises that sea-level rise represents a long-term dynamic risk. Hence, strategic city planning decided to take a scenario-based risk management approach which allows for possible higher sea-levels over the timeframe.

By 2043 Wellington is expecting between 50,000 and 80,000 more people, creating the need for 30,000 more homes (WCC, n.d.). WCC has completed a Planning for Growth survey, presenting four potential growth scenarios to the people of Wellington. The scenario that was most agreed to by the public, for balancing trade-offs, was scenario two; suburban centres (fig. 5.04), either strongly agreed with or agreed with by 66% of respondents. This

scenario encourages development around suburban centres and public transport routes, even if it means more investment in existing water, transport and social infrastructure (e.g. libraries, community centres). Suburban centres support the development of suburban hubs, encouraging communities to flourish. Increased use of public transport anticipates the reduced exposure of natural hazard risk (Global Research Ltd, 2019). Planned investment of Public Transport connects as far out as Johnsonville through Wellington CBD, Newtown, Kilbirnie and finally to the airport. This model supports transport-oriented intensification of employment and housing occurring along this growth spine (WCC, 2015).

02

suburban centre

Image Redacted due to copyright

5 selection of site: kilbirnie

"Some of the areas vulnerable to inundation from sea-level rise are already within flood risk zones, in particular, Kilbirnie, areas within the CBD and Miramar". The frequency and severity of flooding in these areas is likely to increase simultaneously with the increase of sea-levels. These consequences are related to the increase of inundation from the sea and the reduced gradient of land-based flows due to increased sea-levels (Tonkin & Taylor Ltd, 2013).

Kilbirnie has been selected as the setting of this design research, as it faces the risks of population growth

and existing vulnerability to flooding.

The 'Sea Level Rise Options Analysis' report used a 'spider diagram' to provide a visual summary of the balance of impacts across the four factors (well-beings). Kilbirnie is significantly affected socially and economically by 1.5m sea-level rise arising from the inundation of the road to the airport. The value assessments of Kilbirnie are provided (Tonkin & Taylor Ltd, 2013). This research endeavours to research how 'accommodation' and 'expansion' of the coast applies to a community scale.

This report considers response

strategies for Wellington, which cover the broad categories of:

1. Non-intervention (do nothing, or 'unmanaged retreat');
2. Managed retreat;
3. Hold the line;
4. Accommodate; and
5. Expand into the coastal zone.

These strategies contemplate the mitigation options for sea-level rise could range from managed retreat through to 'conventional' protection options like seawalls/floodwalls and property raising or floodproofing.

The interventions considered for Kilbirnie against the cost purposes suggests seawall and stormwater management, soft protection and managed retreat. The literature suggests that the comparison of cost is ordered by; managed retreat costing the least, then hard protection, and finally, soft protection being the most expensive. Kilbirnie is an exception when the sea-levels reach 1.5 metres as the cost of retreating from the area could require the demolition or relocation of major roads and other infrastructure, such as access from the city to the airport (Tonkin & Taylor Ltd, 2013).

Kilbirnie is presented as a case study, to showcase one example of how sea-level rise impacts this specific landscape and the possible and available intervention opportunities.

A 1.5-metre rise in sea-level could have an impact on land, property and valuable infrastructure assets worth the combined value of over \$400 million. The population is considered vulnerable to the effects of sea-level rise, comprising a higher than average proportion of elderly residents, low income and rental properties within the suburb. The affected population dramatically increases from less than 50 in 0.6-metre sea-level rise to approximately 1000 in 1.5-metre rise. Kilbirnie is located on flat topography, making it an ideal candidate for providing community infrastructure. Sea-level rise of 1.5 metres is projected to impact these facilities, such as the Wellington Regional Aquatic Centre; Kilbirnie and Evans Bay Parks; SH1 to Wellington Airport; St Patricks College and the ASB Sports Centre. This inundation affects the residents of all neighbouring suburbs who benefit from these facilities. Kilbirnie is also currently vulnerable to existing hazards, such as flooding, tsunami events and liquefaction. These hazards expect to be exacerbated by sea-level rise. Flooding is expected to increase in frequency and intensity, increased vulnerability to liquefaction as the crust thickness reduces as sea-level rises and groundwater levels affect underground pipe networks, building foundations and storage tanks.

The local environment

Transport:
[SH1 to the Airport, Primary & Secondary Roads]

Topography:
[5 metre contours]

Wind:
[Wind is able to travel between the two hills across the isthmus, through Kilbirnie and Lyall Bay]

Water:
[Coastal areas, harbour to the North and sea to the South]

Fig. 5.06.

Risk

2030

2050

2100

5.4.2
site analysis

Fig. 5.07.

Kilbirnie 3m sea-level rise

Facilities that are affected

Transport:
[SH1 to the Airport, Primary & Secondary Roads]

Residential:
[Primarily semi-detached homes]

Sporting:
[ASB Centre, Kilbirnie Park, Wellington Regional Aquatic Centre, Rec Centre and St Pat's]

Industrail Facilities:
[Tacy Street & Rongotai Road/Jean Batten Drive]

Educational Facilities:
[St Pat's College & Evan's Bay Intermediate]

Community:
[Bay Road, Communtiy Centre, Ruth Gotlieb Library, Indian Association, St Pat's church, NZ Police]

Fig. 5.08.

Kilbirnie 3m sea-level rise

Facility Type:

Residential

Industrial

Sporting

Airport

Transport

Education

Kilbirnie Typology

Fig. 5.09.

Traffic

*Priority of
Traffic Routes:*

Residential

Primary Suburban

Secondary Route

Primary Route

SH1 to Airport

Site Visit Route 01

Fig. 5.10.

The three main response strategies suitable for the suburb of Kilbirnie are managed retreat, a seawall and soft protection options. A single solution is not adequate for an entire suburb. Retaining access to the airport is vital for Wellington, but this does not protect the existing properties from becoming inundated.

Accommodation strategies include canal cities and ferry services. Expansion into coastal zones facilitate creative interventions, including floating suburbs and new or retrofitted stilt cities or canals. Individual dwellings have increased adaptability potential by raising property and floodproofing managed through policy and rules in the District Plan. The Sea-Level Rise Options Report suggests that these are only suited applied to an individual situation, and seawalls and managed retreat are suitable for the application across a community scale (Tonkin & Taylor Ltd, 2013).

Innovative response strategies have not been included within the “options assessment as WCC has elected to focus on options more likely to proceed over the foreseeable planning horizon” (Tonkin & Taylor Ltd, 2013). These futuristic options include sufficient floating islands to house displaced citizens. As this research considers the timeline from 2030 to 2100, these innovative opportunities are the focus as the planning horizon extends, and speculation of the opportunities is required to prepare for any scenario.

Fig. 5.11.

THE ANALYSIS

6.1	<i>The Typologies</i>	109
6.2	<i>Floodable Architecture</i>	111
6.3	<i>Stilted Architecture</i>	125
6.4	<i>Floating Architecture</i>	135
6.5	<i>The Reflection</i>	146

CASE STUDIES

Fig. 6.01.

ana
lysis.

the typologies

This literature covers the three chosen architectural typologies; floodable, stilted, and floating. A discussion is comparing these typologies between both vernacular communities in developing countries and modern western responses in developed countries. This analysis is interested in how each case study responds to the created adaptability criteria. Each typology can engage

with the water and enhance this idea of 'living with water'. This review encompasses projects that have been completed and tested with an innovative response that could potentially alter how we live in the future. Further investigation of individual case studies that are successful provide design solutions for the development of the design.

floodable architecture

floodable architecture

Cuisinart Center for Culinary Excellence
Hafencity Masterplan
Eferdinger Becken, Upper Austria
Watersquare, Benthemplien, Rotterdam
Zak Seine Masterplan by Baca Architects

Fig. 6.02.

stilted architecture

NYC Parks Beach Modules
Tai O Fishing Village, Hong Kong
Kompong Phluk, Tonle Sap Lake
Maori Pataka Building

Fig. 6.03.

floating architecture

New Water development, Naaldwijk
Urban Rigger, Copenhagen, Denmark
Waterside Developments, Whitianga
Chong Khneas, Tonle Sap
City Apps, Waterstudio

Fig. 6.04.

Floodable Architecture has only recently become a purposeful architectural concept. It allows the development of easily removable materials and connections to reduce damage to the significant structural systems and services. This Floodable typology also relates to the engagement of water with urban design, and providing areas which allow water to fluctuate in and out, mitigating risk from

significant infrastructure. Lastly, the term floodable considers when the inundation of water reduces a space, often damaging resources, requiring seasonal replacement or removal. Floodable within an architectural context must consider the sustainability of having to repair or replace elements regularly. With this as a consideration, floodable design might be more efficient at an urban scale.

FLOODABLE

cuisant center

by Tsoi/Kobus Associates

Providence, Rhode Island, USA

The polluted brownfield in a coastal floodplain provided a challenging site for the John and Wales Culinary Arts Program to expand. Tsoi/Kobus Associates from Massachusetts had the task of satisfying state and federal regulations that new flood plain development must design for future storm surges. The design concept originated from beach homes. Blake Jackson, of Tsoi/Kobus Associates, described his firm's design approach as "fail fast, [but] fail cheap", creating a berm and pile-raised building with a sacrificial ground floor layer. Relocation of the heating, electrical and other vulnerable equipment to the higher floors, above anticipated flood levels (A Better City, n.d.; Aiken et al., 2014). Specific glass and brick panels with integrated break-away panels and clips enclose the ground floor lobby and loading dock. The materials are disposable, so when the pressure from the storm-surges exceeds the strength of the material, it disconnects. Their removal maintains the structural integrity of the building without compromising on the primary columns and walls in the event of a flood. This strategy relieves pressure from the significant investment of the whole building. Access into the building is possible from ground level or onto the first floor via the grass berm. The grass berm provides access to the first floor even when the site is in flood (A Better City, n.d.).

Fig. 6.05.

FLOODABLE

floodable ground floor

revetment

multi-purpose levee

strengthening dikes

The industrial activities of the Port of Hamburg declined, which opened up the opportunity for the city to develop within the industrial ports, rather than expanding out to the outlying agricultural land. HafenCity ("Harbour City") had to incorporate flood-resistant design and sustainable architecture as the City is located on the banks of the Elbe River, outside of the protection of Hamburg's dyke system. The design involved the investigation into the creation of a new dyke system for that area of the harbour. However, it was deemed too costly and time-consuming and therefore, was disregarded. Instead, large constructed land mounds called warften are lifted. Transport was prioritised to the high section, allowing access when the other areas flood periodically. Due to the unstable riparian soils, all the development has required structural piles. Parking can be re-located within the warften, increasing the walkability of the district, and relieving the need for surface parking and vehicular congestion (HafenCity, 2006; HafenCity Hamburg, n.d.).

FLOODABLE

Fig. 6.07.

eferdinger becken

Upper Austria

A small community of 154 homes in Eferdinger Becken, Austria lies within the floodplains of the Danube River, which floods regularly. The government employed a passive flood prevention strategy which offered the community 80% of their property values for the exchange of those occupants relocating.

Allocation of the remaining 20% is for demolition and re-cultivation of the land. (de Sylva et al., 2017). Eighty homeowners accepted this offer and relocated to a designated site within the region. This cost the government approximately 325 million Euros. The remaining population lived on the top floor of their homes. The government provided financial support for their renovation costs to make this liveable (de Sylva et al., 2017; EEA, 2017).

This case study provided an example of people choosing to live amongst a flooded environment because of the connection of place. Connection to place is considered in the initial stages of the timelines. The flooding in Kilbirnie is expected to increase, yet this connection of place must be designed for when planning for sea-level rise. People might continue to live in Kilbirnie, despite consistent flooding.

FLOODABLE

Fig. 6.08.

water square

by De Urbanisten

Benthamplein, Rotterdam

Projections suggest the climate is to experience more frequent rain events, which also increase in intensity. Excess rainfall presents a problem for the water management of cities which are densely populated and consisting of almost entirely hard surfaces. Rotterdam is one of these cities, and the Water Square has provided an innovative solution for water storage issues. The design consists of three different basins with a combined storage capacity of 1700m³. Rainwater and runoff from the surrounding surfaces and rooftop collect within the 2 shallower basins. The excess water flows into the deeper basin, which also functions when dry as a central sports area. These basins temporarily submerge. When the rain eases the water drains through the ground, or flow to the nearby Noordsingel canal relieving the city's sewage system. When the Water square is not collecting water, the square provides valuable public space for the nearby residents (Bravo, 2018; RCI, 2012; Wilkinson, 2017). Maintenance of the square is required to maintain its desirable entertaining and recreational qualities (Nooijer, 2011).

absorbent street

depoldering

water storage

water square

FLOODABLE

Fig. 6.09.

zak seine

by Baca Architects

River Seine, Paris, France

Master-planning design has developed plans for a massive regeneration area at risk of flooding along the River Seine, downstream from Paris. Landscape elements integrate with water, providing levels of defence for the city. The design utilises phase planning to prioritise infrastructure, and understand how water inundates the area (The Guardian, 2013). "A thriving mix of uses are created around blue/greenways and corridors to create a unique and economically vibrant new quarter, overlooking the River Seine". Public transport is at the core of the development. Three nodes focus on the main transport opportunities; Rail, River and Road. The nodes form a catalyst of development stimulating revitalisation zones that bring quick enrichment to the area (Baca Architects, n.d.). Waterways link each node and double as a drainage system. A green/blue park absorbs water and the pressure of rainfall on surrounding areas (The Guardian, 2013). The strategy targets the hierarchy of the program, locating land uses by vulnerability, while maintaining access routes (Baca Architects, n.d.). Hence, water flows where the city is less concerned about, such as parklands, landscaping areas and finally some streets (The Guardian, 2013).

floodable park

living shoreline

water square

FLOODABLE

stilt houses

Vietnam

"The Vietnamese term for the flood season 'mùa nước nổi' connotes a time where all things appear floating on water. It is because people try to stay above water. This pivotal yet straightforward strategy allows everyday life to continue during prolonged flooding of 3–4 months" (Liao et al., 2016). The vernacular architecture of stilt housing tolerates this inundation of water that occurs periodically throughout the year. The height of the house is related to the height of the significant flood levels that could occur. Gaps remain between the floorboards allowing ventilation, reducing the force of the waves in the event of the flood. These separations allow floodwater to drain in and out quickly without the loss of possessions. To prevent momentary inundation temporary floors are installed.

floodable ground floor

elevated building

open plan living

Fig. 6.10.

ana
lysis.

stilted architecture

Stilted architecture gained traction in the modern world when Le Corbusier published his series of architectural principles. These design principles describe the 'Five Points of a New Architecture'. These are best embodied in the Villa Savoye in Poissy, France. The principle of Piloti's considered that a grid of columns could replace a load-bearing structural wall, creating a new light aesthetic that makes the ground floor freely available (Les Couleurs, 2018).

This design principle was therefore entirely for aesthetic purposes rather than a responsive solution to any environmental risks; however, it is an appropriate solution for increasing the flexibility and resilience of a project and has been done in vernacular architecture for centuries. It provides more exceptional durability in an environment where waves could penetrate the structure on a shoreline.

STILTED

Fig. 6.11.

nyc beach modules

by Garrison Architects

NYC, USA

modularity

dune restoration

elevated building

open plan living

Hurricane Sandy devastated the coastline of New York City with four-metre storm surges and over 130km winds, destroying thousands of homes and other structures. This catastrophic event highlighted the urgency of design of these coastlines to provide mitigation of these natural disasters. The location of public lifeguards and comfort stations makes them susceptible to being targeted on the coast. Garrisons Architects of Brooklyn, New York designed a resilient modular solution to be deployed 37 times, over 15 sites in 5 months (Garrison Architects, 2013) and 7 months after the storm (Integrated Structures, 2015). The quick turnaround was critical as the units would be installed in highly trafficked areas, and the city was eager for its severely damaged beaches to reopen in time for the 2013 summer season (Integrated Structures, 2015). A modular design achieved the speed of production required through factory production, but also allowed the conventional chassis to provide flexibility of the program to modify from comfort stations, lifeguards stations and offices while still attaining to a variety of site conditions. Accessed by ramps made of aluminium gangplanks, mounted atop concrete legs which raise it above the 500-year flood level. Consideration of the details has allowed these building to be independent; equipped with photovoltaics to provide enough renewable energy for daily use and heat the water. Cross ventilation allows the space to stay calm and skylights illuminate the space during the day, while still gaining spectacular views of the ocean. This design hopes to prevail the next storm surge that hits NYC (Garrison Architects, 2013).

STILTED

Fig. 6.12.

tai o

Tai O, Lantau Island, Hong Kong

This traditional fishing village is on the north-western coast of Lantau Island. The fishing industry has declined in recent years due to the socio-economic changes, whereby the younger population are moving to urban areas for work. Therefore, the village relies on small scale fishing and tourism for their livelihood, and the 3,400 inhabitants are mostly elderly. The mangrove habitat is a vital environment for fishing, contributing to the food source for fish and other aquatic animals. Most of the town centre is elevated 2.90-3.40m above the average sea-level. The town is subject to periodic inundation, especially throughout the summer (Chan et al., 2013). In 1989, the sea wall that protected the village became damaged, flooding the village causing it to be half destroyed. A new sea wall was completed in 2013, which is 3.4m above the mean sea-level. This defence is only capable of mitigating the small-scale annual flooding events (Chan et al., 2013). The proposed wall design was 4 metres high, and intended to have a waterfront promenade, to protect from the storm surges. However, the community objected as it obstructed scenic views that would interfere with tourism (de Sylva et al., 2017). Unfortunately, this defence is only within the 1 and 10-year flood return period (Chan et al., 2013) and following the recent storm surges insurance premiums are at a high, challenging the future of this old fishing village and the elderly population that live here.

mangroves

temporary floodwall

STILTED

kompong phluk

Tonle Sap, Cambodia

Located on the edge of a river that flows into the Tonle Sap Lake is a small community. The placement of the community within the flood zone is significant of the primary income and livelihood revolving around the fishing industry. The height of the stilted community varies with the topography, and ranges from 4 to 8 metres (Au Morris, 2014). Periodic environmental fluctuations transforms the social, ecological and transport networks of this community. The elevated architecture responds to the fluctuating environment, and this adaption has allowed inhabitants to reside there, and take advantage of the productive fishing industry. In the dry season, a wide central road is utilised for transport and drying the fish. Ladders, stairs and multi-purpose platforms supply access to the elevated homes (de Sylva et al., 2017). As the water level rises, boats become the mode of transport, and the ground level roles are transferred upwards to elevated platforms. These platforms act as social gatherings, recreational spaces, shops, markets, fish drying and production platforms (de Sylva et al., 2017) throughout the months where the community is completely inundated with water. This transfer of life happens with little disruption, highlighting the flexibility of these communities (Au Morris, 2014).

open plan living

elevated building

protecting infrastructure

Fig. 6.13.

STILTED

Fig. 6.14.

pataka storehouse

Traditional Maori development, New Zealand

Within a Maori kainga (settlement) after the 15th century, it was common to see a stilted development which identified the pataka (storehouse) (Brown, 2014). It was elevated to store food supplies, and preserve food like fish, kumara (Maori sweet potato), and seeds safe during the winter (Albom, 2015), as well as valuable possessions (Brown, 2014). The exterior finish of the storehouse indicate the quality of the goods that are stored. Hence some were roughly thatched, and others adorned with an abundance of carved designs. In most cases the carved decorations were confined to the front of the Pataka; “the threshold plank, the verge-boards and their vertical supporting planks, together with the interior porch” (Best, 2016). This decoration is a representation of the wealth and prestige of the tribe (Brown, 2014). These storehouses were elevated about 4 ft. from the ground to protect from predators accessing the storehouse. Various devices help prevent the predators from ascending the posts. Access was available by a removable step ladder, so it could be moved into place only when someone wished to enter the store (Best, 2016).

This structure is not a structure designed in response to floods rather for protection from dampness and animals and insects. This case study is relevant as it showcases that stilted architecture is vernacular to New Zealand.

protecting infrastructure

open plan living

elevated building

“In terms of sea-level rise, this is the most resilient form of housing because it moves with the water”, Ingels says. “It’s the only building type that will never flood” Loudrup agrees... “it rises and falls with the water...that’s sustainability in one sense”
- **Bjarke Ingels**

ana
lysis.

floating architecture

The original coastline of Wellington is documented by the plaques saying “1840 shoreline” which now run along Lambton Quay and Willis Street due to the Reclamation of land for the extension of Wellington’s CBD and of buildable flat land in the steep geography. The Palm Springs in Dubai are an example of these artificially constructed landscapes. The construction of this unnatural reclamation of land requires 11.5 km long break wall to protect from threats, such as tsunamis, earthquakes and sea-level rise (Au Morris, 2014). The creation of artificial land is prominent in a lot of other coastal cities; Manhattan, Mumbai and Dubai, however, this process is expensive, and the process is time consuming, as time is needed for the sand to compact to the stage where it is

buildable. It destroys marine life (Olthius, 2012).

Floating architecture is a revolutionary idea which is providing new opportunities for how we approach the development of our cities. Floating architecture reduces the pressure from finding habitable land in expanding coastal cities. Urban design schemes are incorporating water developments all over the world. Floating architecture allows attachable infrastructure to add to existing land. This concept is similar to that of the Reclamation of land, which is a widespread solution; however, floating adds a dynamic variable.

FLOATING

Fig. 6.15.

new water development

by Waterstudio

Naaldwijk, The Netherlands

The Netherlands is below sea-level, and this urban design approach utilises this threatened landscape. This masterplan combines housing, infrastructure, ecology and water storage into a multi-functional zone. "The New Water development will help the surrounding polders by expanding their storage capacity in case of heavy rainfall. The ambition for this project is to set the benchmark for urban development on water in depolderised zones in Holland" (Waterstudio, n.d.). The masterplan encompasses 820,000m² of development, consisting of 1200 homes, of which 600 are floating. "In this water-development project virtually all new water-based concepts and technologies will be used; Floating houses in a row, floating social housing, large floating islands, floating roads, floating gardens, stilt-houses and terp-houses" (Waterstudio, n.d.).

water storage

canal street

floating architecture

FLOATING

urban rigger

by BIG

copenhagen, denmark

The Urban Rigger project responds to the lack of affordable housing available in the centre of Copenhagen. BIG from Copenhagen, Denmark saw an opportunity in the underutilised harbour at the heart of the City. Urban Rigger provides affordable accommodation that provides quality individual student residences, a shared courtyard and roof terraces. The standardised container system allows an extremely flexible building typology (ArchDaily, 2016). The configuration of the containers has optimised the lifestyle of the design. The triangular composition provides privacy for each unit, and frames a sheltered courtyard space, which encourages a social environment within the community. The arrangement also allows for further expansion of the floating community, creating connections between pontoons at ground and first floor levels (BIG, 2016). The Urban Rigger excels in the generation, storage and conversion of power. Solar panels on the roof supply power and a NASA developed aerogel insulates the interiors, (Mun-Delsalle, 2017) recovering 95% of heating (Danfoss, 2016). The Hydro Source Heating converts the surrounding seawater as a free, efficient and clean natural heat source. "The heat pump ensures that 75% of the energy for heating and hot water is extracted from the sea". 15% of the energy consumption is saved with light floor heating (Danfoss, 2016). This engineering is especially interesting as it increases the productivity of the final design. The heat transfer rate from the water is higher than using the ground as a heat source, making this method more efficient, and therefore more productive (Mun-Delsalle, 2017).

modularity

floating architecture

Fig. 6.16.

FLOATING

Fig. 6.17.

waterside developments

by Waterside Sustainable Developments

Whitianga, New Zealand

The rising tourist interest in the town of Whitianga has allowed the engagement of Hopper developments to produce a new marine district in 2019. This development has allowed for the design of 12 floating homes by Waterside Sustainable Development, which is the first attempt at floating architecture in New Zealand. The design concepts allows flexibility of orientation, storeys, layout and deck variations to suit the owner's personal preference. Each with its 18-metre berth, allowing accessibility around the marine district (Waterside Developments, n.d.). Floating architecture has the potential to be revolutionary for housing opportunities and the architectural profession if it gains traction in New Zealand.

canal street

floating architecture

FLOATING

Fig. 6.18.

chong khneas

Tonle Sap, Cambodia

The Tonle Sap Lake in Cambodia experiences extreme fluctuations. During the change of season, the water levels can rise from 1 metre to 10 (Au Morris, 2014). These periodically inundated communities have adapted with these fluctuations, hence evolving their vernacular architecture. Chong Kneas is a floating community to the west of Kompong Phluk, comprised of a marginalised Vietnamese population. During the wet season, containing animals and fish in pens is essential. Aquaculture is becoming more common; this includes the traditional method of rearing the fish in a cage. The seasonal fluctuations of the lake create migration to the lake as the water level falls and rises. These fluctuations encourage the transitional lifestyle of the floating village, where people live in floating homes or houseboats. This typology accomplishes adaptability, which has evolved for the village, which mirrors the changes of the lake (Evans et al., 2004).

FLOATING

Fig. 6.19.

city apps

by Waterstudio

Korail Bosti, Dhaka, Bangladesh

Koen Olthuis, founder of Waterstudio in 2003 exclusively designs and builds floating houses. This architecture provides a 'solution' to the threatening of waterside construction due to growing urban centres and rising sea-levels. The firm has completed more than 200 floating homes and offices primarily in the Netherlands. Waterstudio's portfolio includes luxurious design in Dubai and the Maldives, more modest homes in Europe and the United States to providing floating utilities some of the most impoverished communities in Asia. The City App aims to offer services to slums accessible to water that are prone to flooding or lack resources (Schuetze, 2016). In developing countries, polystyrene combined with concrete has formed the floating foundation. This material and process is often considered unsustainable. Thousands of PET bottles were collected in cages to form a floating foundation, to test whether re-using this material would allow a container to float (Waterstudio, 2016). This test was successful, but also misleading as the project kept the Styrofoam material located to the interior of the floating platforms. This project has the potential to provide multiple uses; including education, water filtration systems, medical clinics or homes. There has already been five City App's applied to the low-income community of Korail Bosti in Dhaka, Bangladesh. The five units consist of a classroom with 20 tablets workstations, a community kitchen, a facility with a public restroom and shower, and another with a back-up generator for electricity. Solar panels located on the roofs provide the units with power (Business Insider, 2018). This project can provide valuable resources to neighbourhoods in developing nations and improve how those occupants live, especially those communities threatened by climate change.

modularity

floating architecture

set
ting.

the reflection

The present analyses indicate that the criteria is useful as a comparative tool. However, it is essential to note that the adaptability of each case study is relative to the situation. Within the site of Kilbirnie, different topographical conditions require different solutions. These case studies have identified the design solutions that make up the Palette of Solutions, allowing easy adjustment to a different setting. Five case studies are marked as influential to the progression of the design research:

Floodable – Zak Seine

The Zak Seine project designed by Baca Architects implements the idea of accommodating water. Identification of significant infrastructure is necessary within the masterplan to determine where is floodable. This response identifies the success of layering different urban solutions to increase spontaneity and resilience of a system, mitigating the risk of significant infrastructure. This project has informed the zones of protection

within the urban design aspects of my research.

Floodable – Water Square

Multi-use design is successful as it allows multiple programs to be executed in one space, increasing efficiency and sustainability of the living environment. The Water Square project highlights that the allocation of water storage space can remain productive when it is not in flood. Increased weather events in urban areas require adequate storage facilities, without minimising desirable public space. The Water square provides a solution as it acts as a recreational area until it becomes a water storage facility for the community. This mixed-use concept needs to be maximised within the design research, at the urban and architectural scale to increase flexibility.

Stilted – Kompong Phluk

This research does not concern a site

that is affected by seasonal flooding. However, the progressive floor levels of the Kompong Phluk community showcases the area of layers of defence, but at an architectural scale. This case study highlights the change of lifestyle that is enforced by water, informing the research that people can adapt to a new lifestyle to maintain their sense of place and culture, when necessary. This is considered in the timeline research.

Floating – Urban Rigger

The Urban Rigger project develops the idea of modular systems at an individual scale that are duplicated to form a community. The design excels in the generation, storage and conversion of power, and utilises the surrounding water to do this. The capabilities that typologies possess highlight the benefits of living on the water. Water has a higher thermal mass than that of the most common construction material, utilising this

6.5.1

case study evaluation

as a design component benefits the efficiency of floating infrastructure and architecture.

Floating – Waterside Developments

Waterside Developments establishes the possibility for floating infrastructure in New Zealand. The design of this complex provides multiple variations to a kit-set plan. Owners have the opportunity to select their preferred orientation, storey height, layout, and deck variations. These variations are possible because of the modular design. The ease of these design variations is influential in the design of the architectural scale of this project. The ability to maximise these variations for the individual increases the overall adaptability of the design, hence making it a more desirable on the economic market. These design variations provide content for the Palette of Solutions, and influenced the iterative design sketches.

Floating - City Apps

Koen Olthius presents an exciting idea with City Apps, which

provide the premise for the design methodology of this research. The floating infrastructure allows a desired program to be temporarily or permanently accessible to the user. Chapter Four acknowledges City Apps as a conceptual idea that challenges the current urban development methods: Why do we continue to build static infrastructure within a dynamic environment? Olthius suggests a flexible, dynamic approach can satisfy the changing needs of our society and explains the idea of Floating City Apps (Olthius, 2012). Floating developments possess the ability to migrate to situations where they are needed, and rotate with the sun, maintaining the desired orientation.

The project is also referred to in the case study analysis, to recognise the diversity of programs and clients catered to by floating infrastructure. It responds to a lack of public facilities within the community — supplying the needs of many through design. This idea drives the design concept behind ‘The Hub’.

These five case studies highlight the influential aspects of design research. The case studies have provided both the development of conceptual ideas, a toolkit of strategies and detailed design solutions. Case study analysis has highlighted the importance of a balance between the four adaptability factors; resilience, governance, spontaneity and affordability. For the criteria to identify a successful case study, consideration of site analysis is required. It is imperative the design of adaptability considers the user,

and the resources based within the communities. The Hub design is accommodating for a community, and therefore, the design variability needs to be considerate of everyone’s needs.

The following chapter will explore the learnings from this analysis by cataloguing all the possibilities within the Palette of Solutions. This design research employs space planning with conceptual models, design iterations with sketches and details of the phase planning of the 70-year timeline.

THE RESPONSE

7.1	<i>Palette of Solutions</i>	154
7.2	<i>Ecological Area</i>	177
7.3	<i>Living on Water</i>	184

Fig. 7.20.

shock + response [2030 onwards]

MORE OCCURRENCE OF FLOODING

The occurrence of flooding is going to occur more and more often in the suburb of Kilbirnie

PROPERTY DAMAGED

Each time the suburb floods damage is caused to property. The environment becomes unpleasant to live in.

PROPERTY MARKET DROPS

The property market drops and there is no longer desire to live in the suburb.

resp
onse.

palette of solutions

This timeline assumption led to the investigation of how urban areas can mitigate flooding. The constructed palettes of solutions are a toolbox from various forms of literature and case studies that similarly respond to flooding or sea-level rise. The degree to which this potential is realised

depends on the selected portfolio of mitigation options and the local circumstances and context. These are compared by the Criteria's four factors to determine the adaptability of the solution, in the context of Kilbirnie, New Zealand.

urban design palette of solutions

deepening summer bed

Fig. 7.01.

lowering groynes

Fig. 7.02.

strengthening dikes

Fig. 7.03.

dike relocation

Fig. 7.04.

lowering of floodplains

Fig. 7.05.

removing obstacles

Fig. 7.06.

water storage

Fig. 7.07.

high-water channel

Fig. 7.08.

temporary floodwall

Fig. 7.10.

depoldering

Fig. 7.09.

protective barrier with seating

Fig. 7.11.

protective barrier with seating

Fig. 7.12.

protective wall with shelter

Fig. 7.13.

deployable floodwall

Fig. 7.14.

walkway berm

Fig. 7.15.

stairway berm

Fig. 7.16.

skate ramp

Fig. 7.17.

concrete berm

Fig. 7.18.

mangroves

Fig. 7.19.

canal street

Fig. 7.20.

water square

Fig. 7.21.

revetment
Fig. 7.22.

multi-purpose levee
Fig. 7.24.

absorbent street
Fig. 7.23.

bio-swale
Fig. 7.25.

floodable park
Fig. 7.26.

living shoreline
Fig. 7.27.

dune restoration
Fig. 7.28.

7.1.1

reflection

Evaluation of each solution against the adaptability criteria identified that engaging and responsive strategies are successful when considering Kilbirnie as the context. These included bio-swales, floodable parks, living shorelines, and dune restoration as the most adaptive. The other viable solutions are water squares, absorbent streets and

lastly, canal streets. This analysis has identified the success of the solution when compared to four factors: resilience, governance, spontaneity and affordability. Application of the relevant solutions create a layered network of engagement strategies to maximise the flood protection of the urban area.

7.1.2

architectural palette

A Palette of Solutions is relevant at an architectural scale also. These are collated from diverse projects that have designed a component to mitigate flooding and sea-level rise risk. This analysis identified architectural typologies that respond

to flooding and sea-level rise, and therefore, provided an opportunity to assess those typologies against this specific context.

dry flood proofing

Fig. 7.29.

floodable ground floor

Fig. 7.32.

wet flood proofing

Fig. 7.30.

elevated building

Fig. 7.31.

floating architecture

Fig. 7.33.

accessibility to maintain

Fig. 7.34.

thermal mass

Fig. 7.35.

eaves

Fig. 7.36.

protecting infrastructure

Fig. 7.37.

amphibious home

Fig. 7.38.

open plan living
Fig. 7.39.

modularity
Fig. 7.40.

Analysis of the criteria identified 3 architectural typologies: floodable, stilted and floating. These typologies generate the selection of case studies for this research and further analysis identifies the appropriate typology to apply to the context of Kilbirnie. Floating architecture has been selected for the site of Kilbirnie, as the harbour provides shelter to the Kilbirnie coastline. Floating architecture also allows maximum adaptability to continuing sea-level rise in the future. The typology of floodable or stilted architecture might be more applicable to a different context; for example, the stilted architecture might better respond to ocean wave environments.

The successful Palette of Solutions are techniques that have been efficient in engaging with the natural environment. Adaptable architectural qualities incorporate passive design techniques to maximise the response to climate and materiality. Accessibility to maintain and protect services are also essential qualities which further excel the resilience of the infrastructure.

Further exploration of the maximum functionality of space is executed. The square and rectangular construction is more affordable to build, more durable and easier to replicate. Modularity promotes ease of construction for any individual and allows for extensions and removals. Brand's Shearing Layers model also supports this model (Brand, 1995).

This research applies this Palette to one scenario and context. Different solutions might be more responsive to a different context or situation. Within this site, different topographical conditions require different solutions. Therefore, this research is utilised as a comprehensive study on sea-level rise, and the responsive design opportunities that are possible.

The Palette of Solutions is a library of design ideas that can be deployed incrementally to progress adaptable and sustainable urban development. It is an idea generator comprised of literature and case studies. Urban and Architectural solutions are compared to the four criteria factors: resilience, governance, spontaneity, affordability. Where possible, the ideas explore various ways of connecting with water. The criteria highlight the appropriate ideas from the Palette of Solutions that are considered adaptable and applicable to the site, illustrating how the Palette of Solutions might be used to an urban context. The thesis, Think Big Act Small, partly influenced the creation of the Palette of Solutions (Roach, 2017).

The Hub is a representation of the future possibilities of Kilbirnie. The research proposes a series of design moves, throughout these 70 years, that are catalysts for adaptable urban development. The Hub takes into consideration future projections expected to influence the way we live in the context of Kilbirnie, Wellington. The key

design interventions operate across scales and disciplines (architecture, landscape architecture, urban design, and installation). The Palette of Solutions are each seen as a separate and disparate move. Instead, the design applies this in a composite manner. Therefore, these combinations of solutions can be executed differently for another setting. The base model of the Hub proposes a floating platform that allows for urban ecological activities to function alongside productive architectural forms. The urban ecological functions protect from unexpected weather conditions, attractive communal green spaces and productive resources. The architecture functions allow for more productive and renewable resources intending to create a zero-carbon economy. The Hub is presented as a single physical model to speculate the damage sea-level rise can cause the living environment. The intention is to engage the imagination of the audience, sparking change in their lifestyle, removing consistency and routine and encouraging adaptability and spontaneity.

resp
onse.

72 ecological area

The successful urban design palette of solutions apply to the context of this research, the suburb of Kilbirnie. This design showcases how Kilbirnie might progress from a flooding suburb into a fluctuating ecological area. This progression of the timeline relies on the Council's involvement in mitigating the flooding impact of the suburb by using natural solutions. The design considers

zones of defence, applying multiple Palette of solutions to create layers of mitigation. These zones are combined to create a comfortable inhabitable space. The high-level design aligns with the main driver of using an adaptive strategy that combines these solutions to provide an area which allows the water to fluctuate and avoid significant infrastructure.

Fig. 7.41.

ecological zones

RELOCATION TO THE HILLS

Due to unpleasant flooding a large proportion of the people choose to relocate to higher ground

DESERTED

Kilbirnie's population drops. The anchor retail facilities are now harder to access and people generally avoid the suburb

CHEAP AND CONNECTED

The people who remain in the flooded suburb either:

1. Cannot afford to move elsewhere
2. Require cheaper expenses
3. Connection to Kilbirnie and their homes.

WETLAND

The Council:

1. Provides subsidy for the people who wish to relocate from Kilbirnie
2. Provides subsidy for flood damage
3. Begins landscaping the existing green spaces into wetlands and swales

Ecological Area Design

- **Dune Restoration:**
- **Water square:**
- **Absorbent streets:**
- **Living shoreline:**
- **Bio-swale:**
- **Floodable Park:**
- **Canal Streets:**
- **Strengthening Dikes:**

Fig. 7.42.

Fig. 7.43.

becoming amphibious

CHANGE OF LIFESTYLE

People who decide to inhabit Kilbirnie need to invest in living within a flooding community

INVESTMENT

Council subsidises the attachment of amphibious technology to existing homes to allow them to sit above the water within their own plot

This investment is made by the owner to make living within this environment more comfortable

resp
onse.

73 living on water

Fig. 7.44. Humanity lifestyle shall change if forced to occupy the water. These diagrams reveal the considerations and design measures that are required to create a comfortable environment for the people living on water.

water environments

Fig. 7.45.

Fig. 7.46. Consideration of the environment on the water differs from land is required. Water has a greater thermal mass, allowing it to store heat more effectively. This means a body of water is cool during the day, and warm at night, when compared to land. This benefits the arhcitecture.

Fig. 7.47.

connecting for communal [2050]

CHANGE OF LIFESTYLE

The flooding has reduced the public facilities within the suburb, and removed the possibility for outdoor space

ADDING ON

The residents can add on platforms to their respective plots to create outdoor space and communal areas to enjoy

SENSE OF COMMUNITY

Encourages the sense of community and improves the social interactions

THE DESIGN

8.1 *Iterative Design*

190

The following section explains what the design research addresses and the primary concepts that will be incorporated throughout.

de
sign.

31

the process

Initial explorations that consider various typologies that respond to water. These explorations explored at the residential scale, and drawings are evaluating their respective adaptability. The analysis provided further selection of the 3 typologies; floodable, stilted and floating to explore.

Fig. 8.01.

Fig. 8.02. The analysis of this research allowed the shift from the residential to the community scale. This diagram shows the step by step thinking process applied to create the traditional form of the perimeter block.

The neighbourhood endeavours to explore how the arrangement of space can provide a sense of intimacy and increase interactions. The parti diagrams considered assessability, appropriate communal space, and effective orientation to maximise passive design techniques.

perimeter block conceptual modelling

Fig. 8.04. Modelling and drawing over allowed the human scale to be realised. There was a contrast of intimate and public spaces. I believe this is successful as it generates social interaction. This process produced quick realisations of an idea.

the neighbourhood conceptual modelling

Fig. 8.05.

Fig. 8.06. Sketching over a form produced quick modular ideas. The level of detail increased, however this method was limited. It was difficult to extend from the existing form to produce something organically, and to access the connection and access between public and private zones.

Fig. 8.07.

Ecological
Protection

Productive
rooftops

Intimate
spaces

Sheltered
Internal
Courtyard

Multi-floor
access

Moveable
Facades

Fig. 8.08.

These two methods of conceptual modelling and sketch detailing produced very different outcomes. Conceptual modelling realised the larger scale, and produced quick high level thoughts. The detailed sketches produced a connection between the architecture and urban

scale. Together, these processes were successful at iterating ideas.

These qualities are identified as promoting dynamic built and social environments and help inform the presentation of The Hub.

the
qualities

Fig. 8.09.

no boundaries

NO BOUNDARIES

The water level has increased to the stage where the existing boundary plots are no longer recognisable

DISORDER

The current grid system and suburb layout is ignored and people begin to occupy the space more organically

LAND DENSIFICATION

Densification of Wellington is occurring on land
People are becoming more comfortable with living with densification in the capitol city

WATER SUBURB

Popularity increases for the lifestyle on the water

Fig. 1.10.

Fig. 8.11.

development of the market

POPULARITY INCREASES

The lifestyle of living on the water becomes more popular

FLOATING ARCHITECTURE

People are interested in investing in the floating infrastructure

MODERN SOLUTIONS

Modern solutions become a possibility, changing the typology of the suburb.

THE H4B

9.1	<i>Urban Precedents</i>	209
9.2	<i>Circular Economy</i>	221
9.3	<i>Design decisions</i>	223
9.4	<i>Physical Model</i>	228

Fig. 9.01.

connecting to the hub [2100]

DEMAND FOR LIFESTYLE:

The demand to live on the water increases. Popular within families for a lifestyle that decreases the densification

MARKET FOR SUSTAINABILITY:

The interest to live sustainable is high. People are invested in mitigated their footprints

COMMITMENT FROM THE COUNCIL:

Council invests in 'hub' platform structures. They provide a zero waste lifestyle opportunity with social community spaces

▸
(xxxx)

h u b

[noun]

01. the central part of a wheel, rotating on or with the axle, and from which the spokes radiate.

02. the effective centre of an activity, region, or network.
the central or main part of something where there is most activity

9.1.0

definition.

the
hub.

urban precedences

The final design provides the facilities of a central community. This community presents a near zero-waste lifestyle opportunity in the market, attracting sustainable living. The individual home can attach to this communal 'hub', providing community spaces for people to interact, while also providing energy, water, food, and waste systems.

The hub produces resources for the occupants docked to it, and consequently disposing of all these resources. This requires engagement from the community. The hub incorporates natural defences surrounding the architecture, to provide green spaces and resilience against unexpected weather events.

tokyo bay

by Kenzo Tange

Image Redacted due to copyright

The Tokyo Bay design was intended for the 1960's, when cities were experiencing the height of urban sprawl. Tange attempted a model that would accommodate the cities continued expansion by creating a series of linear interlocking loops that extended across Tokyo Bay. Tokyo was in a state of paralysis, as the expansion of the city centre caused land shortage and traffic congestion. Mobility determines the structure of the city and hence, how people live within it.

The design involves two components, the core and the pilotis. Core systems link urban arteries with the buildings, whereas the piloti system constitute the spatial links between

private and public areas, "where the flow of traffic meets with stable architecture". This design proposes the unification of both the core and piloti's into a single system.

The hierarchy of the transport system allows consistency and efficiency, but removes flexibility. Circulation zones were to be separate from human spaces, which enhanced flexibility. Tange's vision was that the city become adaptable to both external growth and internal regeneration (Lin, 2007). This model presented the ideas that have been circulating since the 1960's, highlighting that floating infrastructure is not a new technology.

9.1.1

superblock, brasilia

by Lucio Costa

Brasilia began in 1956, with Lucio Costa as the principal urban planner and Oscar Niemeyer as the principal architect. Design informed the construction of the city, rather than being left to organic growth. The key underlying concept of the Superblock is the creation of four zones, with independent functions: living, working, recreation and circulation (New World Encyclopedia, 2019). The composition of the city is arranged per a hierarchical road system, with slower speed limits within the residential zones, and increased speed as you leave these zones. This structure was to encourage social interactions at the ground floor, within public space and under architecture through the pilotis.

The residential areas are composed of superblocks, 240 x 240m in dimension with housing, educational services such as primary and kindergarten. An extended area is intended for commercial buildings, the assemblage of community facilities: secondary schools, theatres, churches and recreational facilities. Each Superblock has minimal variations to the program; residential, commercial, service, religious, educational, mixed, leisure and sport. Spatial variations within the superblocks were possible,

regarding the deployment of the building, treatment of the gap, the composition of the openings in the facades, the degree of visual permeability and movement at ground level. These variations affected the social interactions occurring within each Superblock. Ribeiro and de Holanda (2015) established the basic design principles of the Superblock: “overall dimensions uniform maximum, up to six floors with pilotis, the peripheral band lined with 20m wide; and separation of pedestrians and vehicle traffic”. These principles created a uniform presentation identifiable even when variations in the size and shape of the architecture, installation of the blocks and finishing materials were used (Ribeiro & de Holanda, 2015).

Diversity and concentration of activities attract a larger audience for public spaces. Costa’s invention of the Superblock proposed buildings loose in abundant green areas and zoning activities. These qualities informed the design of The Hub. This precedence showcases how an area can provide facilities for a certain number of people, which are grouped and duplicated, with slight variations, to multiply communities. This layout of resources is interesting for this research of The Hub.

sustainable city

by Diamond Developers

Image Redacted due to copyright

The Sustainable City of Dubai is a \$354 million development, committed to creating a circular economy model (Garfield, 2018). It is the first operational net-zero city in Dubai, creating an example to be compared internationally for high-quality, but efficient living. Social, Economic and Environmental Sustainability are all targeted to achieve a three-tiered strategy. The City is directly related to reducing the resources we consume, intending to prevent a 2-degree increase in the average temperature of our planet above pre-industrial levels (Diamond Developers, 2019).

A circular economy model informed the tools; such as passive design strategies, water and waste recycling, urban farming, and the encouragement of electric transport and ownership: a free electric golf cart or the subsidy of US\$10,000 toward an electric vehicle.

The Sustainable Plaza provides a multi-use plaza comprised of retail, restaurants, cafes, offices and apartments. The Plaza generates rental revenue, whereby a portion of the rental revenue is going to pay all the maintenance and service fees required for the city, eliminating these costs for the occupant.

A basic desert technology solution has existed for more than 40 years, in farms all across the Arabian Desert. The system is straightforward, called ‘fans and pads’. In this scenario, four fans blow air out of the dome, creating a negative pressure internally, this causes the suction of air into the dome, through the constantly damp, corrugated cardboard technology called ‘pads’. In the Sustainable City, this is reducing the temperature from 45 externally to a more pleasant 30 degrees. Extraction of energy from the ‘solar farms’ (solar panels located on the roofs above the carparks) provide the energy for the fans. These solar panels provide the energy for these communal systems (Fully Charged, 2017).

The Sustainable City provides this project with a built example of an urban system attempting a net positive design solution. It showcases how the fundamental ideas of a circular economy might be successful at a city scale. These simple design solutions benefit the design of The Hub. This local technology of the fans and pads air conditioning system is particularly relevant to the circular economy of the hub design.

sisyphus & entropy

by Arnaud Leurgin

Image Redacted due to copyright

9.1.4

This thesis presents a modular architectural form which is repeatedly attached to a central communal system to provide an adaptable and affordable response to the recurring floods in Nanjing, China. “This thesis attempts to rationalise two diverging practices in Architectural discourse, that of Western pedagogy and that of the ‘Other’”.

This research is relevant as it targets a flood-prone scenario that also highlights the importance of indigenous vernacular design solutions. The design responds to this issue by using the core idea of having central public infrastructure which supports multiple individuals. Arnaud’s design approach presents a detailed understanding of the parts and construction of the attachable individual home. The design explores the opportunities of the modular design its capacities. This idea differs

from the ‘Hub’, as that considers one replicable communal core, with diverse individual components.

A singular unit consists of three structural components; the floor, wall and roof, along with one cosmetic component; the facade panel. Each component can be modified and repurposed, and floatation devices support seasonal fluctuations. The flooring structure consists of a grid base with structural frame beneath, allowing storage and attachment possibilities. A lattice flooring system allows accessibility from within the subfloor structure, allowing for adaptable storage and barrel maintenance.

This particular lattice flooring system and the respective flexibility it provides encourages this style of the grid for the foundation of the floating Hub design (Leurquin, 2017).

floating island

by Blue21

9.1.5

French Polynesia is one of the at-risk island nations, with a third of the country slowly submerging by sea-level rise. The development of Floating architecture has provided a ‘life raft’ for those remote or sinking island nations, for protection of their food supply, energy and inhabitable space (Czapiewska, 2018).

Sea-steading is a unique governing framework of decentralisation. Modular, floating structures, or sea-steads provide the opportunity for the evolution of new societies and forms of governance to occur. The detachable platforms allow for additional or breakaway communities, which enables a high level of evolvability and a quick rate of adaptation (Blue Frontiers, 2018).

Blue Frontiers is collaborating with Tahitian designers to develop a comfortable aesthetic that takes cues from Polynesian shipbuilding. The island consists of research facilities to provide constant monitoring of the human impacts. The design intends to reduce the shadow, allowing sufficient light to reach the coral reef below (Marris, 2017).

The floating island in French Polynesia aims to mimic a natural landscape. A similar idea has developed throughout this research with the combining of the urban palette of solutions. The floating Hub Design utilises natural defences, and height as means to create natural drainage, provide storage within the landscape and allow more north-facing sun into the interior spaces.

circular economy

A circular economy employs a restorative and regenerative approach by intention and design to our living environments. It replaces the disposable concept with restoration, shifting towards the use of renewable energy, eradicating the use of toxic materials, which harm return to the biological environment. This model aims for the elimination of waste through the superior design of materials, products, systems and business models (World Economic Forum, n.d.). The Ellen MacArthur Foundation presents the concept of circular economy, to re-define growth, to build economic, natural

and social capital. This model encourages the shift from a linear economy of 'take', 'make', 'dispose' to a circular system that returns and enriches the originating system. The concept is influenced by the natural environment or 'biological cycle' which enriches the landscape, as waste becomes valuable resources or nutrients for the next user. Acceptance that this biological process is functional and efficient allows this transition to begin.

Three principles relating to a circular economy; design out waste and pollution, keep products

and materials in use, and the regeneration of natural systems. The current linear approach utilises finite resources and disposes of toxic materials (Ellen MacArthur Foundation, 2011).

The model distinguishes between technical and biological cycles. Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture or (in the last resort) recycling. Biological cycles include food and biologically-based materials, and design allows feedback back into the system through composting and anaerobic digestion to regenerate living environments (Ellen MacArthur Foundation, n.d.).

Design of biodegradable products minimises waste with compostable products and packaging. Technological products are returned, and disassembled and regenerated, providing resources for the next product. The Ellen MacArthur Foundation (2011) suggests the reconsideration of the term 'ownership', and instead promotes a license from the manufacturer. Products would return to the production company, dismantled into technical and biological products.

This research has projected that a global circular model employs from current day through to the year 2100. International research and strategies support the model of a circular economy; including the Government of South Australia, the London Waste and Recycling Board, the Finnish Innovation Fund Sitra, and finally the Ellen MacArthur Foundation website (Ministry for the Environment, n.d.-a). Accommodating this model expects benefits over the traditional linear economy that include:

1. long-term financial savings;
2. increased local job opportunities;
3. encouragement of technical innovation,
4. reducing the quantity of harmful waste production
5. potential to reverse the impacts on our living environments and climate change.

Relevant to the New Zealand context, the Ministry of Environment hopes to "work and partner with these innovative businesses who are looking to pilot and explore these circular economy concepts through the supply chain" (Ministry for the Environment, 2018). This model generates prosperity long-term.

design decisions

Fig. 9.07.

Fig. 9.08.

Site analysis of Kilbirnie identified these strategies to maximise passive design concepts within the design of the Hub. These strategies are represented in the drawings of the Hub in the following section. Consideration of the context is vital for designing efficiency.

Fig. 9.09.

at sea large
basement area
possible

expected
minimum
0.8 m to 1.0 m

increase
winter sun

allows space
for services
and soil

Fig. 9.10.

The site of Kilbirnie is experiencing an expected sea-level rise of 0.8m in the year 2100. Therefore if the floating Hub is to be utilised within these areas of the suburb it is not possible to have a large basement area. Therefore, the floating platform must be built up to allow for services underneath. This landscaped topography can double as protective urban areas.

Fig. 9.11.

Fig. 9.12.

Fig. 9.13.

9.4

physical model

the
hub.

Process of forming the physical model of the Hub. The foam was added inbetween the grid structure of the floating platform to highlight the need for soil in areas of ecology.

9.4.1

physical model

Fig. 9.14.

Fig. 9.15.

Fig. 9.16.

Fig. 9.17.

Fig. 9.18. The North Elevation clearly shows the storage barrels which are located below sea level. These provide water and waste storage in the centre, and buoyancy to the perimeter. The grid system allows access to these facilities through the north south direction.

West Elevation.

Fig. 9.19.

Fig. 9.20.

9.4.7

The design of The Hub recognises a 70-year development of mentality, lifestyle and, consequently, architecture. The physical model is a depiction of The Hub, designed for Kilbirnie. This research has presented how the city of Wellington might adapt to the risk of sea-level rise. The final design has made changes taking into considerations the functionality and productivity of the design. Each design move has a reason that increases the modification ability for the individual. Developing The Hub provides significant infrastructure that considers the primary and collective needs of inhabitants to the predominant risks of sea-level rise.

This drawing shows how residential homes might attach to the Hub to utilise its services

Fig. 9.23.

chapter

THE REFLECTION

10.1	<i>The Hub</i>	244
10.2	<i>The Process</i>	246

1 the hub

The Hub embodies my research. It is a reflection of the key ideas and the context within which it sits. The combination of modelling and drawing over is a successful process of creating form and relating to the existing built fabric. Drawing, computer illustration, digital and physical modelling work in synergy to present an architecture of possibility. By presenting the scheme as one composite 'model', moving between scales is essential – strengthening the 'BIG' and 'small' thoughts and acts of the project. The physical model deliberately rejects technicality and specificity. Instead, the multi-faceted

style of the design research aimed to produce a final product that is progressive and fluid. This idea of impressionistic representation encourages a provocative vision for the future of architecture in Kilbirnie. It seeks to engage an audience in the possibility of the future. A future that is approachable and desirable, despite the impending confrontation of sea-level rise.

The following evaluation revisits the adaptability criteria formed in Chapter Four. This aims to highlight the influence of the criteria on the final design representation. The four

the hub.

1

adaptability factors are resilience, governance, spontaneity and affordability.

Resilience: Resilience of the Hub is designed at the urban and architectural scale. Zones of protection provide layers of defence against water. A living shoreline and dunes provide perimeter shelter, advancing to a floodable park network with integrated bio swales. The central public space of the built form includes a multi-use water square, providing recreational and water storage opportunities. The topography of the Hub provides natural resilience to sea-level rise and unexpected weather events

Governance: My interpretation of the research and the progression of the timeline, and the Council's respective involvement as sea-level rises. District plans and policies will employ response strategies to sea-level rise, and 'Lapping at the edges' presents floating infrastructure as an opportunity for Wellington, and the wider country.

Spontaneity: The urban network of the Hub employs natural systems to prioritise the fluctuations of water away from significant architecture. This increases the ability for The Hub to respond to spontaneous events. Floating architecture increases spontaneity of the design creating maximum adjustment of location and orientation.

Affordability: Affordability includes the financial and social components of a design. The design process of form making and conceptual modelling analysed both the urban scale and the human scale. The Hub building combines the traditional perimeter block with the designed suburb, with the intention to maximise protection and interaction. Modular open plan architecture is presented, to maximise the adaptability of the form and program. Passive design techniques are incorporated into the idea to promote the affordability financially.

102

the process

the hub.

The thesis, 'Lapping at the edges' was driven by two problems: that sea-levels are rising, which pose an increasingly relevant risk to coastal developments, and the continuation of static infrastructure within a dynamic environment. The research explores how architecture can be adaptable in the context of sea-level rise through the process and outcome of research-led design. The research gives focus to both research and design methods, with evaluations being made throughout the research development, progressing from reviewed literature, to conducting my research and

finally the design applications. Literature reviews and case studies provide a comprehensive insight into the strategy. These led to two approaches: the core concept and 'Idea' of Adaptability and the 'Execution' to the context and issue of sea-level rise. The research conducted alternated between these two different approaches to inform one another. I believe the iterative design process was useful for testing ideas quickly. This process produced the alteration in scale, from residential design to community scale.

The Palette of Solutions offered a response for the future. It is flexible, changeable and responsive over the 70-year timeline. The Palette of Solutions presented a range of ideas that are derived from the case studies, formulating a generic compilation of flood management solutions. Site analysis of Kilbirnie implements the selection of suitable solutions. If time allowed, applying the process and criteria to other coastal site would be valuable. This would help to further redefine and identify any aspects that might be unique to the Kilbirnie site, in order to ensure the conclusions are widely applicable. Within this site, different topographical conditions require different solutions. Therefore, this research is utilised as a comprehensive study on sea-level rise, and the responsive design opportunities that are possible.

The design of adaptability must consider the user, and the resources based within the communities. The Hub design is accommodating for a community, and therefore,

the design variability needs to be considerate of everyone's needs. The Palette of Solutions allows a range of solutions to be presented, relevant to situations that require action to flooding and sea-level rise impacts. It allows the user of this Palette the opportunity to respond with a unique solution. This has the potential to alter our relationship with water, utilising design to encourage how to 'live with water'. From the outset, the purpose of this research was to create principles, criteria and strategies that identify how new innovative architectural solutions, existing infrastructure and adapted solutions, over time, adapt to the consequences of sea-level rise on their living environment.

The 70-year timeline of this research requires a speculative design approach. High-level design allows the concept to be realised, but still maintains the adaptability of the project. Innovative technologies will transform our living environments in the future, potentially increasing the potential

of adaptability. Various contextual situations may require particular solutions. Similarly, diverse socio-cultural and economic requirements of communities may dictate specific solutions, not necessarily 'floating'. The facilitator must consider the application of these solutions to the site and explore the idea with various community stakeholders, to ensure the architectural result reflect the predominant and collective needs of the people.

While the Hub may be adaptable, we have to recognise that it may have limitations and with the unpredictable nature of climate change, new solutions may yet to be invented. Integrating these solutions into a circular economy concept can generate prosperity long-term. Hence, detailed design at the landscape and architecture scale, such as drainage management and material selection, are not included in the scope of the research. The research instead presents a concept that's relevance will endure across time.

It is clear that developing floating public infrastructure alone will not

fulfil the requirements to protect the coastal residents of Kilbirnie in the future. However, the design process of the research presents a new speculative approach to responding to sea-level rise out to 2100, in Kilbirnie. This allows the possibility of increasing existing infrastructure resilience and promoting adaptability of the built environment. The design identifies that changing from large and small scale must work simultaneously in coastal suburbs.

The Hub utilises the necessary interdisciplinary approach to adapting architecture to sea-level rise, encompassing architecture, landscape architecture, urban design, and strategic phase planning. A physical model represents The Hub, which aims to encourage a positive attitude towards the future of sea-level rise and the innovative architectural solutions that can respond to a changing climate. The research has achieved the intention to generate awareness of the impacts of sea-level rise, and create criteria which encourage an adaptive approach to these dynamic living environments.

BIBLIOGRAPHY

11.1	<i>Works Cited</i>	252
11.2	<i>List of Figures</i>	262

- A Better City. (n.d.). 'Designing with water'—What strategies can businesses take? A Better City. Retrieved 13 June 2019, from <http://www.abettercity.org/news-and-events/blog/designing-with-water-what-strategies-can-businesses-take>
- Adeyeye, K., & Emmitt, S. (2017). Multi-scale, integrated strategies for urban flood resilience. *International Journal of Disaster Resilience in the Built Environment*, 8(5), 494–520.
- Aiken, C., Chase, N., Helendrung, J., & Wormser, J. (2014). *Designing with Water: Creative Solutions from around the Globe* (Volume 2; Preparing for the Rising Tide Series). The Boston Harbor Association & Sasaki Associates. http://www.bostonharbornow.org/wp-content/uploads/2017/02/PRT2-Designing-with-Water_Full.pdf
- Albom, R. (2015, April 1). Auckland Museum's Maori Collection. Albom Adventures. <https://www.albomadventures.com/auckland-museum/>
- ArchDaily. (2016, October 4). Urban Rigger / BIG. ArchDaily. <https://www.archdaily.com/796551/urban-rigger-big>
- Au Morris, J. Y. (2014). Adaptive Landscape Architecture: Embracing amphibious environments and empowering community sustenance [Victoria University of Wellington]. https://viewer.waireto.victoria.ac.nz/client/viewer/IE963100/rep/REP963173/FL963174?dps_dvs=1560397094525~377
- Baca Architects. (n.d.). Zac Seine Masterplan Paris. Baca Architects. Retrieved 3 July 2019, from <https://www.baca.uk.com/zac-seine-masterplan-paris.html>
- Baca Architects. (2016). Nijmegen. Baca Architects. <https://www.baca.uk.com/nijmegen.html>
- Bankoff, G. (2001). Rendering the World Unsafe: 'Vulnerability' as Western Discourse. *Disasters*, 25(1), 19–35. <https://doi.org/10.1111/1467-7717.00159>
- Barredo, J. I. (2007). Major flood disasters in Europe: 1950–2005. *Natural Hazards*, 42(1), 125–148. <https://doi.org/10.1007/s11069-006-9065-2>
- Beavan, R. J., & Litchfield, N. J. (2012). Vertical land movement around the New Zealand coastline: Implications for sea-level rise. GNS Science Report. <https://www.gns.cri.nz/static/pubs/2012/SR%202012-029.pdf>
- Bell, R. G., & Hannah, J. (2019). Update to 2018 of the annual MSL series

and trends around New Zealand.

- Bell, R. G., Lawrence, J. H., Allan, S., Blackett, P., & Stephens, S. (2017). Coastal hazards and climate change: Guidance for local government. Ministry of the Environment. http://natlib-primo.hosted.exlibrisgroup.com/NLNZ:NLNZ:NLNZ_ALMA11298516500002836
- Best, E. (2016). The Maori as he was: A Brief Account of Life as it was in Pre-European Days—Habitations, Storehouses, Villages, The Pa Maori. New Zealand Electronic Texts Collection. <http://nzetc.victoria.ac.nz/tm/scholarly/tei-BesMaor-c6-7.html>
- BIG. (2016). Projects—Con Urban Rigger. BIG | Bjarke Ingels Group. <https://big.dk/#projects-con>
- Blue Frontiers. (2018, March 21). Building Floating Islands for Seasteading. Steemit. <https://steemit.com/introduceyourself/@bluefrontiers/blue-frontiers-building-floating-islands-for-seasteading>
- Brand, S. (1995). *How buildings learn: What happens after they're built*. Penguin.
- Bravo, D. (2018, June 18). 'Water Square' in Benthemplein. Public Space. <https://www.publicspace.org/works/-/project/h034-water-square-in-benthemplein>
- Brown, D. (2014, October 22). Maori architecture—Whare Maori – [Web page]. Te Ara - the Encyclopedia of New Zealand. <https://teara.govt.nz/en/maori-architecture-whare-maori/page-1>
- Business Insider. (2018, April 20). These floating buildings are made from thousands of plastic bottles that can withstand flooding. Business Insider Nederland. <https://www.businessinsider.nl/waterstudio-floating-city-app-buildings-sea-level-rise-2017-11/?international=true&r=US>
- Chan, F. K. S., Adekola, O. A., Ng, C. N., Mitchell, G., & McDonald, A. T. (2013). Coastal flood-risk management practice in Tai O, a town in Hong Kong. *Environmental Practice*, 15(3), 201–219.
- Czapiewska, K. (2018, October 23). FLOATING ISLAND IN FRENCH POLYNESIA. Blue21. <https://www.blue21.nl/portfolio/floating-island-in-french-polynesia-2/>
- Danfoss. (2016). Urban Rigger. Danfoss. <https://www.danfoss.com/en/about-danfoss/insights-for-tomorrow/urban-rigger/>

Dangendorf, S., Marcos, M., Müller, A., Zorita, E., Riva, R., Berk, K., & Jensen, J. (2015). Detecting anthropogenic footprints in sea level rise. *Nature Communications*, 6(1), 1–9.

de Sylva, S., Vale, B., & Vale, R. (2017). 'Primitive Attitudes' and Traditional Practices—Looking Back for Sustainable Solutions to Future Flood Disasters. In M. A. Schnabel (Ed.), *Back to the Future: The Next 50 Years* (pp. 5–15). The Architectural Science Association (ANZAScA).

Diamond Developers. (2019). The Sustainable City. The Sustainable City. <https://www.thesustainablecity.ae/>

EEA. (2017). Relocation as adaptation to flooding in the Eferdinger Becken, Austria. Climate ADAPT. <https://climate-adapt.eea.europa.eu/metadata/case-studies/relocation-as-adaptation-to-flooding-in-the-eferdinger-becken-austria>

Ellen MacArthur Foundation. (n.d.). Concept. What is a circular economy? Ellen MacArthur Foundation. Retrieved 26 February 2020, from <https://www.ellenmacarthurfoundation.org/circular-economy/concept>

Ellen MacArthur Foundation. (2011, August 28). Re-thinking Progress: The Circular Economy. Youtube. <https://www.youtube.com/watch?v=zCRKvDyyHml>

Evans, P., Marschke, M., & Paudyal, K. (2004). Flooded Forests, Fish, and Fishing Villages in Tonle Sap, Cambodia. <https://doi.org/10.13140/RG.2.1.4962.9520>

Fully Charged. (2017, March 17). Sustainable City. <https://www.youtube.com/watch?v=WCKz8ykyl2E>

Garfield, L. (2018, January 30). The United Arab Emirates is building a \$354 million city with driverless cars, greenhouses, and solar-powered villas. *Business Insider Australia*. <https://www.businessinsider.com.au/dubai-sustainable-city-uae-2018-1?r=US&IR=T>

Garrison Architects. (2013). NYC Parks Beach Restoration Modules. Garrison Architects. <http://www.garrisonarchitects.com/projects/nyc-parks-beach-restoration-modules>

Geis, Donald. E. (2000). *By Design: The Disaster Resistant and Qulaity of Life Community*.

Global Research Ltd. (2019). Planning for Growth, Growth Scenario Engagement (p. 117). Wellington City Council. https://planningforgrowth.wellington.govt.nz/__data/assets/pdf_

<file/0015/2931/Wellington-Future-Growth-GR-FINAL-18-06-2019-2.pdf>

Gunderson, L. H., & Holling, C. S. (2002). *Panarchy: Understanding Transformations in HUMAN and Natural systems*. Island Press.

Gunderson, L. H., Holling, C. S., & Light, S. S. (1995). *Barriers and bridges to the renewal of ecosystems and institutions*. Columbia University Press.

HafenCity. (2006). HafenCity Hamburg Der Masterplan (p. 48). https://www.hafencity.com/upload/files/files/z_en_broschueren_19_Masterplan_end.pdf

HafenCity Hamburg. (n.d.). HafenCity—The genesis of an idea. Retrieved 10 February 2020, from <https://www.hafencity.com/en/overview/hafencity-the-genesis-of-an-idea.html>

Hansson, K., Danielson, M., & Ekenberg, L. (2008). A framework for evaluation of flood management strategies. *Journal of Environmental Management*, 86(3), 465–480. <https://doi.org/10.1016/j.jenvman.2006.12.037>

Holling, Crawford S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4(1), 1–23.

Holling, C.S., & Gunderson, L. (2002). Resilience and adaptive cycles. In *Panarchy*. Island Press.

Houlié, N., & Stern, T. A. (2017). Vertical tectonics at an active continental margin. *Earth and Planetary Science Letters*, 457, 292–301.

INNOVA Ezine. (2018). Nijmegen, the EU Green Capital 2018. Urban Climate Adaptation. <https://www.urbanclimateadaptation.net/ezone1/>

Integrated Structures. (2015, January 23). NYC Parks Beach Restoration Modules. Integrated Structures. <http://integratedstructure.com/blogpost1/>

Kellert, P., & Napier, M. (1995). Squatter Architecture? A Critical Examination of Vernacular Thoery and Spontaneous Settlement with reference to South America and South Africa. *Traditional Dwellings and Settlements Review*, 6(2), 7–24. JSTOR.

Knueven, L. (2019, August 15). Climate change experts agree on the last place they'd invest for the future: Waterfront property [Business News]. *Business Insider Nederland*. <https://www.businessinsider.com/why-not-buy-waterfront-property-climate-change-experts-2019-8>

Lafarge Holcim Foundation. (2015, February 3). The Dryline – BIG’s vision for New York City. <https://www.youtube.com/watch?v=xkpNSTg6LXs>

Lafarge Holcim Foundation2. (2015, September 27). The Dryline: Global Holcim Awards Bronze 2015 – Project Overview. <https://www.youtube.com/watch?v=wScadZRzCKE>

LafargeHolcim Foundation3. (2014, March 31). The Dryline: Urban flood protection infrastructure project summary. LafargeHolcim Foundation. <http://www.holcimfoundation.org/Projects/rebuilding-by-design>

Les Couleurs. (2018, August 29). The five points of a new architecture. Les Couleurs. <https://www.lescouleurs.ch/en/journal/posts/the-five-points-of-a-new-architecture/>

Leurquin, A. (2017). Sisyphus and Entropy, Adaptive Architecture in Flood Prone Nanjing [Online, Victoria University of Wellington]. https://viewer.waireto.victoria.ac.nz/client/viewer/IE1029644/rep/REP1029660/FL1029661?dps_dvs=1579124455692~932

Liao, K.-H., Le, T. A., & Nguyen, K. V. (2016). Urban design principles for flood resilience: Learning from the ecological wisdom of living with floods in the Vietnamese Mekong Delta. *Landscape and Urban Planning*, 155, 69–78. <https://doi.org/10.1016/j.landurbplan.2016.01.014>

Lin, Z. (2007). Urban Structure for the Expanding Metropolis: Kenzio Tange’s 1960 Plan for Tokyo. *Journal of Architectural and Planning Research*, Summer(24:2), 109–124.

Magnan, A. K., Colombier, M., Billé, R., Joos, F., Hoegh-Guldberg, O., Pörtner, H.-O., Waisman, H., Spencer, T., & Gattuso, J.-P. (2016). Implications of the Paris agreement for the ocean. *Nature Climate Change*, 6(8), 732.

Marris, E. (2017). Why fake islands might be a real boon for science. *Nature News*, 550(7674), 22–24. <https://doi.org/10.1038/550022a>

Masson-Delmotte, V. (2018). Summary for Policymakers (H. O-Portner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Pean, R. Pidrock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield, & P. Zhai, Eds.). IPCC. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

Min, S.-K., Zhang, X., Zwiers, F. W., & Hegerl, G. C. (2011). Human contribution to more-intense precipitation extremes. *Nature*,

470(7334), 378.

Ministry for the Environment. (n.d.-a). Circular economy - Ohanga amiomio. Ministry for the Environment. Retrieved 26 February 2020, from <https://www.mfe.govt.nz/waste/circular-economy>

Ministry for the Environment. (n.d.-b). The Impact of Climate Change on Flooding. The Impact of Climate Chnage on Flooding. Retrieved 6 February 2020, from <https://www.mfe.govt.nz/publications/climate-change/tools-estimating-effects-climate-change-flood-flow-guidance-manual-loc-6>

Ministry for the Environment. (2018). Redesigning our thinking—A circular economy. Vimeo. <https://vimeo.com/258906748>

Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., Van Vuuren, D. P., Carter, T. R., Emori, S., Kainuma, M., & Kram, T. (2010). The next generation of scenarios for climate change research and assessment. *Nature*, 463(7282), 747–756.

Mun-Delsalle, Y.-J. (2017, April 13). Denmark’s Urban Rigger And BIG Architects Revolutionize Student Housing By Floating It On The Water. *Forbes*. <https://www.forbes.com/sites/yjeanmundelsalle/2017/04/13/urban-rigger-and-big-architects-revolutionize-student-housing-by-floating-it-on-the-water/#53f584026bd2>

New World Encyclopedia. (2019, December 13). Brasilia, Brazil. New World Encyclopedia. https://www.newworldencyclopedia.org/entry/Brasilia,_Brazil

NIWA. (2017). Sea levels and sea-level rise [Research Institute]. NIWA. <https://www.niwa.co.nz/natural-hazards/hazards/sea-levels-and-sea-level-rise>

Nooijer, R. de. (2011). Water squares | Urban green-blue grids. <https://www.urbangreenbluegrids.com/measures/water-squares/>

Olthius, K. (2012, March 22). Floating City Apps—Koen Olthuis—TEDxWarwick. <https://www.youtube.com/watch?v=9ppflhX5eSw>

OMA. (2013). Resist, Delay, Store, Discharge: A Comprehensive Urban Water Strategy. OMA. <https://oma.eu/projects/resist-delay-store-discharge-comprehensive-urban-water-strategy>

Ramírez-Lovering, D. (2008). Opportunistic urbanism. RMIT Publishing. https://books.google.co.nz/books?hl=en&lr=&id=Fwuz6eig_xlC&oi=fnd&pg=PA5&dq=opportunistic+urbanism+Diego+Ramirez-Lov

ering&ots=h4wmEHsvKS&sig=kU49UgkvlqxmoJcpt0Jib1cYYtg&redir_esc=y#v=onepage&q=opportunistic%20urbanism%20Diego%20Ramirez-Lovering&f=false

- RCI. (2012, September 17). Water plaza Benthemplein Rotterdam. <https://www.youtube.com/watch?v=kujf4BTL3pE>
- Rhein, M., & Rintoul, S. R. (2013). Observations: Ocean (H. Freeland, S. Garzoli, & Y. Nojiri, Eds.). Intergovernmental Panel on Climate Change. http://www.climatechange2013.org/images/report/WG1AR5_Chapter03_FINAL.pdf
- Ribeiro, M., & de Holanda, F. (2015). Urbanity in Brasilia's superblocks. Proceedings of the 10th International Space Syntax Symposium, 15. http://www.sss10.bartlett.ucl.ac.uk/wp-content/uploads/2015/07/SSS10_Proceedings_056.pdf
- Rijkswaterstaat. (n.d.-a). Sea level rise [Webpagina]. Retrieved 13 June 2019, from <https://www.rijkswaterstaat.nl/english/water/water-safety/sea-level-rise/index.aspx>
- Rijkswaterstaat. (n.d.-b). Storm surge barriers [Webpagina]. Retrieved 12 June 2019, from <https://www.rijkswaterstaat.nl/english/water/water-safety/storm-surge-barriers/index.aspx>
- Ruimte voor de Rivier. (n.d.). ROOM FOR THE WAAL. Ruimte Voor de Rivier. Retrieved 2 July 2019, from <https://www.ruimtevoorderivier.nl/room-for-the-waal/>
- Ruimte voor de Waal. (2014, February 6). 29 01 14 Nijmegen Omarmt de Waal English. https://www.youtube.com/watch?time_continue=20&v=wYM1e2ANUFU
- Sasaki. (2014). Sea Change: Boston. Sasaki. <https://www.sasaki.com/projects/sea-change-boston/>
- Schuetze, C. (2016, November 28). A Dutch Architect Offshores the Future of Housing—The New York Times. <https://www.nytimes.com/2016/11/28/arts/design/offshoring-the-future-of-housing.html>
- Sen Nag, O. (2018, June 18). Countries With The Longest Coastline. WorldAtlas. <https://www.worldatlas.com/articles/countries-with-the-most-coastline.html>
- Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P. M. (2013). Climate change 2013: The physical science basis. Intergovernmental Panel on Climate

Change, 1535.

- The Guardian. (2013, January 15). Britain's first 'amphibious house' designed to resist flooding. <https://www.youtube.com/watch?v=1SM6eZ-QuV8>
- Tonkin & Taylor Ltd. (2013). Sea Level Rise Options Analysis (p. 169). Wellington City Council. <https://wellington.govt.nz/~media/services/environment-and-waste/environment/files/61579-wcc-sea-level-rise-options.pdf>
- van der Nat, A., Vellinga, P., Leemans, R., & van Slobbe, E. (2016). Ranking coastal flood protection designs from engineered to nature-based. *Ecological Engineering*, 87, 80–90. <https://doi.org/10.1016/j.ecoleng.2015.11.007>
- Walker, B., Holling, C. S., Carpenter, S., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social–ecological Systems. *Ecology and Society*, 9(2). <https://doi.org/10.5751/ES-00650-090205>
- Walker, B., & Salt, D. (2012). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Island Press. <https://books.google.co.nz/books?hl=en&lr=&id=NFqFbXYbjLEC&oi=fnd&pg=PR1&dq=resilience+thinking:+sustaining+ecosystems+and+people+in+a+changing+world+walker+and+salt&ots=6oN0XCXZMd&sig=bsWhHaX5NN-jcY4l3tF-iFye8lo#v=onepage&q&f=false>
- Walrond, C. (2005, February 8). Natural environment—Coasts [Web page]. Te Ara - the Encyclopedia of New Zealand. <https://teara.govt.nz/en/natural-environment/page-2>
- Walters, C. J. (1986). *Adaptive management of renewable resources*. Macmillan Publishers Ltd.
- Waterside Developments. (n.d.). Whitianga Waterways. Waterside Sustainable Developments. Retrieved 17 June 2019, from <https://watersidedevelopments.nz/waterside-whitianga/>
- Waterstudio. (n.d.). New Water, Naaldwijk, The Netherlands—Waterstudio. Retrieved 17 June 2019, from <https://www.waterstudio.nl/projects/new-water-naaldwijk-the-netherlands/>
- Waterstudionl. (2016, March 18). Final test for Floating City App before it is shipped to Bangladesh. YouTube. <https://www.youtube.com/watch?v=Rp6V80-Ve7A>

- WCC. (n.d.). Planning for Growth. Retrieved 8 February 2020, from <https://planningforgrowth.wellington.govt.nz/>
- WCC. (2015). Wellington Urban Growth Plan (p. 74). Wellington City Council. <https://wellington.govt.nz/~media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/wgtn-urban-growth/wgtn-urban-growth-plan2015.pdf>
- WCC. (2016). Low carbon capital: A climate change action plan for Wellington 2016-2018. Wellington City Council. <https://wellington.govt.nz/~media/services/environment-and-waste/environment/files/low-carbon-capital-plan-2016-2018.pdf?la=en>
- Wilkinson, T. (2017, March 2). Water Square, in Rotterdam, The Netherlands by De Urbanisten. Architectural Review. <https://www.architectural-review.com/buildings/water-square-in-rotterdam-the-netherlands-by-de-urbanisten/10017644.article>
- World Economic Forum. (n.d.). From linear to circular—Accelerating a proven concept. World Economic Forum. Retrieved 26 February 2020, from <https://reports.weforum.org/toward-the-circular-economy-accelerating-the-scale-up-across-global-supply-chains/from-linear-to-circular-accelerating-a-proven-concept/>

**Unless otherwise stated, all
images are authors own.**

Figure 2.01: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 3.10: Render of the Big U, “The Harbour Berm”, an elevated path through the park. (2014). Retrieved from <http://www.rebuildbydesign.org/our-work/all-proposals/big-u>

Figure 4.01: Drawing is influenced by: Walker, Brian, and David Salt. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, DC: Island Press, 2012.

Figure 4.02: Drawing is influenced by: Walker, Brian, and David Salt. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, DC: Island Press, 2012.

Figure 4.03: Drawing is influenced by: Walker, Brian, and David Salt. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, DC: Island Press, 2012.

Figure 4.04: Drawing is influenced by: Brand, Stewart. How Buildings Learn: What Happens after They’re Built. Penguin, 1995.

Figure 4.05: Drawing is influenced by: Au Morris, Jade Yu’An. ‘Adaptive Landscape Architecture: Embracing Amphibious Environments and Empowering Community Sustenance’. Victoria University of Wellington, 2014. https://viewer.waireto.victoria.ac.nz/client/viewer/IE963100/rep/REP963173/FL963174?dps_dvs=1560397094525~377.

Figure 4.06: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 4.07: Drawing is influenced by: Tonkin & Taylor Ltd. ‘Sea Level Rise

Options Analysis’. Wellington, N.Z.: Wellington City Council, June 2013. <https://wellington.govt.nz/~media/services/environment-and-waste/environment/files/61579-wcc-sea-level-rise-options.pdf>.

Figure 5.04: Wellington City Council. (2019). Scenario 2: Suburban Centre Focus. Planning for Growth (p. 16). photograph, Wellington.

Figure 7.01: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.02: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.03: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.04: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.05: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.06: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. Journal of Flood Risk Management, 12(1). doi: 10.1111/jfr3.12448

Figure 7.07: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. *Journal of Flood Risk Management*, 12(1). doi: 10.1111/jfr3.12448

Figure 7.08: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. *Journal of Flood Risk Management*, 12(1). doi: 10.1111/jfr3.12448

Figure 7.09: Drawing is influenced by: Busscher, T., Brink, M. V. D., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch “Room for the River” program. *Journal of Flood Risk Management*, 12(1). doi: 10.1111/jfr3.12448

Figure 7.10: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.11: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.12: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.13: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.14: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

[30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf](https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf)

Figure 7.15: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.16: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.17: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.18: Drawing is influenced by: Holcim Awards. (2014). Rebuilding by Design: Urban flood protection infrastructure, New York, Ny, Usa. New York. Retrieved from https://src.lafargeholcim-foundation.org/dnl/3cfc0088-30a6-4283-9e2a-cdbdc2f72034/HA14_NAM_A4_Silver.pdf

Figure 7.20: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.21: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.22: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.23: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.24: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.25: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.26: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.27: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.28: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.29: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.30: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.31: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.32: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.37: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 7.38: Drawing is influenced by: Sea Change: Boston. (2014). Retrieved August 5, 2020, from <https://www.sasaki.com/projects/sea-change-boston/>

Figure 9.02: The urban plan for Tokyo. (2016). Retrieved from <https://archeyes.com/plan-tokyo-1960-kenzo-tange/>

Figure 9.03: Monumental Axis and Brasilia Tv Tower, Downtown Brasilia, Brazil. (2018). photograph, Brasilia, Brazil. Retrieved from <https://lacgeo.com/brasilia-world-heritage-site-brazil>

Figure 9.04: Locatelli, L. (2017). Building orientation was a critical design choice at the Sustainable City, where homes face north and shade each other. By limiting direct sun exposure, air conditioning units are 40 percent smaller. photograph, Dubai, United Arab Emirates. Retrieved from <https://www.nationalgeographic.com/environment/urban-expeditions/green-buildings/dubai-ecological-footprint-sustainable-urban-city/>

Figure 9.05: Leurquin, A. (2017). Macro Design Structure. Sisyphus and Entropy; Adaptive Architecture in Flood Prone Nanjing (p. 120). photograph, Wellington: Victoria University of Wellington.

Figure 9.06: Blue Frontiers' floating island concept. (2018). Retrieved from <https://www.businessinsider.com.au/libertarian-peter-thiel-utopia-seasteading-institute-2018-3?r=US&IR=T>